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THE SUPERHEATING OF STEAM.

A Communication made to "The Industrial Society of the North of France," by AIMÉ WITZ, Engineer of Arts and Manufactures, and Professor in the Free Faculty of the Sciences at Lille.

Translated from "L'Energie" of June 20th, 1903,

BY BENJAMIN F. ISHERWOOD, CHIEF ENGINEER UNITED STATES NAVY, MEMBER.

HISTORICAL.

The steam engine left the hands of Watt complete in all its mechanical parts; that great intelligence also enriched science by sane observations on the nature and properties of steam, showing himself to have been a consummate scientist as well as an ingenious mechanician; he invented the fly-wheel, the crank, the centrifugal governor, the parallel motion, and all which constitutes the steam engine; he invented the separate condenser and the expansive use of steam. In advance of the admirable discoveries of Hirn, and with the intuition of genius, he comprehended the interaction of the heat of the steam with the metal of the cylinder, and, in

order to prevent it, he invented steam jacketing the cylinder; he also suggested to Hornblower the expansion of steam in compounded cylinders; one thing only appears to have escaped him, namely, superheating the steam after its generation in order to at least greatly lessen, if not to absolutely prevent, the interaction above referred to.

There is much difficulty in determining to whom belongs the glory of this important invention.

Mr. Raffard* has exhumed from the Repertory of French Patents in the "Conservatoire des Arts et Metiers," the specification of a Mr. Becker, mechanician of Strasbourg, dated the 20th November, 1827, relative to a high-pressure engine in which the steam before entering the cylinder is raised to a very high temperature above its temperature in the boiler. The patent mentions a superheating to 410 Fahrenheit degrees.

Alsace is thus truly the cradle of superheating, and the obscure name of Becker passes to posterity with those of the masters of the Alsatian school who will be mentioned later.

Bryan Donkin† gives the honor of the invention to J. Howard of Bermondsey, who, in 1832, realized a notable economy by means of superheating apparatus. Dr. Haycroft, of Greenwich, commenced in 1835, and with equal success, the practice of superheating; but no authentic documents exist describing the apparatus adopted by these inventors.

Superheating belongs also to the North, for Raffard found a patent issued to Quillacq, dated the 3d July, 1849, for the use of steam "non-saturated and superheated"; the apparatus was applied to a Cornish boiler having an internal furnace with which it communicated by means of equilibrium valves; a supplement to the patent, added in the same year, shows a superheater (Quillacq named it a reheater of steam) of annular form placed in the current of the hot gases of combustion, with a provision for putting it out of use in case of need, and which was also a regulator of the superheating. A Mr.

* "Bulletin Technologique," September, 1892.

† "Engineering," 7th April, 1893: "On the use of superheated steam in steam engines."

Moncheuil, in 1850, obtained a second certificate of addition to Quillacq's patent, the addition being for a tubular superheater "composed of a group of small tubes placed within a large tube through which passed the flame or hot gases from the furnace."

Raffard believes that he can include himself among the early promotors of superheating, and cites his patent of 1851 in evidence; this patent relates to a superheater for drying expanded steam, and was placed in the steam room of the boiler itself, but there must be distinctly understood that this apparatus, otherwise very interesting, was only a dryer, and that it could not in any manner produce superheating, that is to say, increase of temperature above the temperature normal to the saturated steam of the boiler, since it was immersed in that very steam.*

Mr. E. Bède, at that time a Professor in the University of Liège, made, in 1854, experiments on superheating in the spinning factory of Saint Léonard, and the only reproach that can be made against them is that they were too timidly made. The distinguished Professor employed a copper tube of U form, which he placed in the smoke conduits for the purpose principally of vaporizing the entrained water and of drying the steam. He took out a Belgian patent, dated the 27th of September, 1854.

Marc Seguin, of Lyon, in 1855 experimented with a superheater formed of iron tubes immersed in a mass of cast iron for the purpose of protecting them against occasional very high temperatures; they were heated to redness. Mr. Lencauchez, who described these experiments, informs us that the Farcot steam engine, to which the apparatus was attached, adapted itself very badly to the too high temperature of the steam used in it.

* Raffard's method was to reduce the pressure and consequently the temperature of the boiler steam by expansion as it passed through his superheater. And as the steam after its expansion is subjected to the temperature of the same steam before its expansion, the expanded steam will become superheated by the difference of the two temperatures. The vaporization of entrained water, and the drying of the steam, and the superheating of the steam, are all caused simultaneously by the expansion of the steam. The temperatures of the steam before its expansion and after its expansion are the temperatures normal to the pressures before and after the expansion.—TRANSLATOR.

But to the immortal Hirn, the great thermodynamist, the scientific glory of Alsace, belongs with just title the invention of rational superheating. His patent of the 12th November, 1855, describes a *hyper-thermo generator* formed of a group of tubes placed in the flue in the middle of the gases of combustion hot enough to impart to the steam a high degree of superheating.

These tubes were of cast iron, which metal was chosen "because of its unalterability," said the patent; the joints were metallic and were formed of a copper ring with sharp edges strongly compressed between the flanges by screws; the group of tubes was placed in the flue at the foot of the chimney. In all cases there were valves which permitted the whole or a part of the hot gases to act upon the group of tubes, and thus to regulate at will the degree of the superheating.

Hirn's patent is a very important document in the history of superheating. It is mentioned with so much the greater emphasis as this great originator, this fecund inventor, this ingenious mechanician, took out only three patents during his long and brilliant career.

Hirn's first experiments on the effects of superheating commenced in 1856, and were made on the celebrated steam engines at Logelbach, since become classical owing to the importance of the researches of which they were the subject. The first was a beam engine of one cylinder without steam-jackets and with four valves; the steam valves were operated by a differential movement which enabled them to be closed at any point in the stroke of the piston, so as to produce any measure of expansion desired for the steam. The steam was supplied in a more or less superheated state, and Hirn valued at 20 per centum the economy produced by a temperature of 410 Fahrenheit degrees; and at 47 per centum the economy produced by a temperature of 473 Fahrenheit degrees. Then he experimented on a compound or Woolf steam engine with steam-jacketed cylinders. The economy produced by the superheating was again clearly shown, and was valued at

from 12 to 15 per centum. He now resolved to separately ascertain the economy produced by the steam jacketing alone, and by the superheating alone by not admitting steam into the jackets. The superheating was then more economical by 8 to 10 per centum "comparatively with what was obtained with saturated steam and steam jacketing."* The superheating was consequently more economical than the steam jacketing.

Hirn recounts how he was deceived in the application of superheating to a compound steam engine without steam jacketing, in the environs of Colmar. An economy of from 25 to 30 per centum was expected, an economic loss of 4 per centum was obtained. This check was later explained and attributed to the special design of the single steam valve which was used for performing the multiple function of operating both cylinders, but which produced a saturation of the superheated steam, thus sending as a net result only a more considerable loss to the condenser. The lesson was not lost on Hirn, who deduced from it important considerations for the rational employment of saturated steam.

He praised a superheating of 446 Fahrenheit degrees. This condition of moderate superheating realized what was a very satisfactory functioning to him; and in 1876 he was able to say that certain steam engines had worked under it during 20 years without any wear or any deterioration whatever.† The Alsatian school does not appear to have exaggerated the thesis of its master, and Hallauer fixed at 482 Fahrenheit degrees a limit that it was not advisable to pass. The important experiments made with such éclat by Hirn, Leloutre, Hallauer, etc., clearly established the end to be attained, namely, the prevention by superheating of the cooling produced in the cylinder during the expansion and the exhaust; and of restricting, if not entirely annulling, the liquefactions which take place during the admission. They have shown that the water of this liquefaction is the enemy, and

*"Analytical and Experimental Exposition of the Mechanical Theory of Heat," by G. A. Hirn, Volume II, page 84. 2d edition. Paris. 1876.

†Hirn, "Analytical Exposition, etc.," Volume II, page 122.

that in the last analysis it is necessary to have the metal again dry at the end of the stroke of the piston, so as to lose nothing to the condenser.

This result can be obtained in a certain measure by the addition of steam jackets to the cylinder, but much more surely by superheating the steam. Nevertheless, there must be acknowledged that though the steam jackets are less economical, their application is easier, they do not cause any injuries, nor require any precautions, nor any special knowledge; while, on the contrary, the superheaters are exposed to deterioration and to destruction by overheating; the industrials who use them have on their hands the case of an apparatus always delicate and sometimes dangerous, and when an accident occurs they have no recourse against the contractors, who naturally endeavor to avoid the responsibility, and to excuse themselves on the ground of incompetent management. On the other hand, an excess of superheating carbonizes the lubricating oil, causes valves and pistons to grip, and destroys the packings of the stuffing boxes; hence, steam jackets should be preferred to superheaters. The same considerations militate in favor of multiple-expansion cylinders, which should thus supersede superheating. This, in fact, is what happens, and the builders of steam engines make their efforts in that direction.

The same evolution has taken place in England.

John Penn introduced superheating in the steamers of the Peninsular and Oriental Steamship Company in 1859, with great success; long-continued experiments made in the Woolwich Arsenal showed an economy of coal of 30 per centum. Parson, Partridge, Pilgrim, Siemens, also established superheaters which were often merely dryers, and always gave only a slight superheating. On board the *Ceylon* the temperature of the superheated steam was 131 degrees Fahrenheit above the saturation temperature, which produced an economy of 25 per centum. On board the *Nepaul*, over 50 per centum of economy was obtained. With single-cylinder engines, supplied with slightly superheated steam at a press-

ure of about 35 pounds per square inch above the atmosphere, the consumption of coal was from 2.42 to 2.65 pounds per indicated horsepower. These results were considered as very encouraging at that time; but equally as good were obtained from compound engines supplied with steam of 70 pounds per square inch above the atmosphere. Now, with equal economy, the superheating is sure to go out of use for the reasons above stated.*

Ghislain in Belgium, Wethered in America, and others in Germany and elsewhere, installed superheaters with as much economy but with no more perseverance than in Alsace. They tried the process, and after a short time abandoned it. Messrs. Dollfus, Mieg & Company, at Mulhouse, placed in their establishment an engine of 200 horsepower with superheater; they soon removed the superheater, although they declared it increased the power of the engine. La Compagnie des Messageries, et la Compagnie Transatlantique established superheaters on board of their vessels, but they never renewed them. The battleship *Fontenoy*, of the French Navy, had a superheater installed which was the subject of a eulogistic report by the Minister of Marine in 1862, but this did not save it.

What was the complaint against it?

The subjection to it, or constraint which it entailed upon the use of the engines, the breakages in them that it caused, the gripments in them to which it exposed them, all as before stated. The pretence was made that horizontal cylinders were nowise proper for the use of superheated steam because their ovalization, considered at that time as inevitable, caused a greater leakage of superheated than of saturated steam.

Briefly, while the principle of superheating was accepted, its practical application was ignored. Also, the technical works posterior to 1862 did not even mention it. The "Aide-Memoire" of Claudel, of 1867, that mine of useful information, omits superheating, the word itself not being found in

* Interesting experiments were made by Isherwood, Loring and Emery; a résumé of them is given by Thurston in his "Treatise on the Steam Engine."

the Table of Contents. The "Théorie des Machines à Vapeur," by E. Bède, of 1863, is mute on this subject. The "Théorie des Moteurs à Vapeur," published in 1872 by Professor Dwelshauvers-Dery in "La Revue Universelle des Mines," spoke with much science of liquefaction, of high pressure, of great measures of expansion, of waste space, and of steam jacketing, but neglected the effects of superheating. Mr. Pochet in his "Nouvelle Méchanique Industrielle," 1873, only mentions superheating to discountenance it. Resal, in his "Traité de Mechanique Généralle," 1876, says superheating has been renounced because it entrains more disadvantages than advantages.

It is then not at all astonishing that at the Vienna Exposition, of 1873, no prize had to be given to any superheater; Mr. Charles Meunier-Dollfus, in his admirable Report presented to the Industrial Society of Mulhouse (29th October, 1873), did not even refer to this lacune of the Exposition, which proves that he was not astonished, and that he did not regret it; superheating was no longer the order of the day. Mr. Lencauchez summed up the situation in a scientific communication made to the civil engineers of France, the 20th of August, 1890, by saying that "if the employment of dry steam was to be investigated, that of superheated steam ought to be set aside as completely unrealizable in industrial practice, *at least for the present.**

This reserve of the perspicuous engineer should be maintained; in fact, before superheating can become practical a metal must be found capable of resisting high temperatures, capable of replacing the hemp packing of stuffing boxes with incombustible material; lubricants which will not turn into cart grease, but which will retain their lubricating quality under high temperature.

Now this progress has been realized rapidly enough.

Since 1888 has been manifested a return, timid though it be, yet undeniable, towards superheating, which has been too much disparaged.

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* "Memoirs of The Society of Civil Engineers of France," 1890; "Advantages of High Pressure Steam in Compound Engines," by A. Lencauchez.

In 1889 was seen at the Exposition Messrs. Lagosse and Bouché's drying reheater of steam. It was a battery of U-shaped tubes placed in the bottom of the chimney and traversed by the steam current. Mr. Uhler also exhibited a dryer—the name of superheater was carefully avoided—and Mr. Olry, in his important report took the precaution to say that "the dryers which were so often added to multitubular boilers are never subjected to a high temperature, and ought not, consequently, to be considered as superheaters.*

But the makers of superheaters soon became bolder, and Mr. Uhler commenced constructing them as such in 1890. He adopted the Field tube suspended in the current of hot gases, and, at first, inserted in a cast-iron box, and afterwards in a plate-iron box.

From this moment a revolution took place in the ideas on this subject, and an energetic movement was made to realize superheating. Gehre, in Germany, used tubes secured in plate iron and having a very large aggregate surface. This superheater was placed in the base of the chimney. Schwoerer, who had been Hirn's distinguished secretary, and had received his latest ideas on this subject, returned to the winged tubes, which he made of Niederbronn cast iron, and united by the Hirn joint. This appeared to him to have had the greatest success, as he recently stated that he had 4,800 superheaters in use in all countries.

At the Paris Exposition in 1900, and since, have appeared superheaters made by Steinmuller de Gummersbach, and by Petry-Dereux de Liège and Hering, all formed of U-shaped tubes, of straight tubes, or of tubes curved into coils. With unwelded tubes drawn from thin metal of the first quality, all the joints being out of the fire and otherwise so conditioned as not to be in danger of injury from it; with free dilatation and a good circulation of steam through the tubes; efficient and durable apparatus are made; the problem is not far from being solved, and superheating can be employed without injury. There remains one difficulty, that of moderating the

* Revue technique de l'Exhibition de 1889. 6e partie t 1, p. 500.

superheating at will; of protecting the group of superheating tubes from the action of the heat between the time the fire is lighted and the time the engine is set in motion; or during the stoppings of the engine when there is no steam passing through the superheater; the most rational method consists in putting it out of circuit by means of valves operated by hand, which allow the current of hot gases to be deflected into an appropriate channel around the superheater, instead of allowing them to pass through it. When the arrangement of the boiler does not permit this means to be employed, recourse can be had to filling the superheater with water, but this exposes it to the formation of scale, the results of which would be disastrous. To moderate the superheating and to limit it to any degree wished, the superheated steam can be mixed, by means of suitable valves, with saturated steam drawn directly from the boiler for that purpose; this is a good process.

In the multitubular boiler the superheater is differently formed; it is a prolongation of the tubes that the steam current traverses on its way to the steam drum. Roser forms it at the side of the furnace; Niclausse places it in the middle of the steam-generating tubes; Belleville put it above them; Babcock & Wilcox, de Naeyer, etc., locate it on the empty angle between the tubes and the water and steam drum. Long discussions could be made as to the relative advantages of these arrangements.

The degree of the superheating evidently depends on the extent of the surfaces which produce it. There is generally given from 10 to 30 per centum of the steam-generating surface, and the endeavor is made to restrict the temperature to about 572 degrees Fahrenheit. Schmidt d'Aschersleben (Saxony) in 1892 desired to give a more intense superheating, and by employing a superheating surface five times as great as that of the steam-generating surface the temperature of the superheated steam rose to 716 degrees Fahrenheit and higher. Notwithstanding the very ingenious precautions taken to protect the first part of the superheating surface by supplying it with very wet steam, the coils of the Schmidt

boiler were so greatly injured by the high temperature that they did not last long. Mr. Serpollet found that he had very exceptional conditions in the case of his superheating tubes, but neither Schmidt nor he appears to have persevered in their designs, and today, like all others, they content themselves with moderate superheating.

This principle of moderation in superheating seems now to prevail, and the proof is seen in the Exposition at Dusseldorf, an Exposition that has made an era in superheating: there, as in Paris in 1900, the firm of Worthington used independent superheating. At Dusseldorf a great number of superheaters were in active use, namely, Hering's, Reichling's, Schwoerer's, Heizmann's, Koch's, etc.. This last apparatus was adapted to a boiler with an interior furnace, and was formed of a vertical assemblage of tubes suspended by a chain in the flue, so that the superheating surface could be varied and, consequently, the superheating temperature. The firm of Dingler exhibited an independent superheater, which apparatus, although giving evidently a less economy, had the great advantage of separate regulation from the draft of the boiler; it could also receive the steam from a battery of boilers, and in that case it is to be recommended, but the preference will always be given for the utilization of the waste heat from boilers by placing the superheating apparatus in the flue.

Under these conditions even a moderate superheating gives remarkable results, for the best steam engines, provided with all the improvements accumulated by theory and practice during the last forty years, have their economy increased by it to an appreciable degree, which will be demonstrated in the second part of this article, and the why and how given.

II. THEORY OF SUPERHEATING.

Theory has sometimes preceded practice, but oftener the practicians propose the problems which the theoricians solve. The steam-engine had functioned for a long time before Sadi

Carnot discovered that heat was converted by this motor into work; and yet he failed to attain the complete explanation given by Seguin and by Meyer of the exact method by which units of heat are transformed into foot-pounds.

Likewise, before Hirn took out his patent of 1856 thermodynamists had unconsciously heated steam out of contact with its generating water, but the practicians would never have obtained any advantage from these first attempts if the scientists had not traced out the road, showed them how to follow it and warned them against false paths.

Hirn did not restrict himself to empty formulas; he sowed ideas with a full hand, but the seed unequally germinated; steam jacketing and multiple expansion ripened faster; now, however, the day of superheating has arrived, and the harvest promises to be abundant.

What should first be done in commencing an inquiry into the facts that have been already acquired? The endeavor should be made to demonstrate that the theory explains them and could have discovered them. For that purpose this work is a timid and modest contribution to the theory of superheating.

For the appreciation of the service resulting rendered by superheating, the assurance must first be had that it really does increase the economic performance of steam engines. With that object there can be compared the results in the following table, No. 1, of a number of experiments which have been made on different engines with and without it.

The economic gain by superheating appears evident from the above comparative table in which are included many types of steam engines and the most varied models with flat valves, Corliss valves, Sulzer valves, and the piston valves of Van den Kerchore; the column of Fahrenheit units of heat consumed per hour per indicated horsepower witness to a real progress accomplished by even moderate superheating. There can be guaranteed without risk of injury to the metal by overheating, a consumption of 5,400 to 7,200 Fahrenheit units of heat per indicated horsepower per hour, according to the

Table No. 1.—Economic Efficiency of the Best Steam Engines.

Types of steam engine.	Condensation	Experimenters.	Date of experiment.	Diameters of the cylinders, in inches.	Stroke of the pistons, in feet.	Number of double strokes made by the piston per minute.	Pressure of steam, in pounds per sq. in., above atmosphere.	Indicated horsepower developed by engine.	Steam superheated, in Fahr. degrees.	Temperature, in degrees Fahr., of the steam as used.	Consumption per hour per indicated horsepower. Weight of steam, in pounds.	Consumption per hour per indicated horsepower. Units of heat, F.
WITH DRY SATURATED STEAM.												
Single-cylinder	Without	Delafond	1884	19.6850	3.6089	62.7	103.54	236.712	0.0	339.93	21.2084	25,145.25
Single-cylinder	With	Delafond	1884	19.6850	3.2803	59.9	103.83	154.849	0.0	340.12	16.2701	19,291.54
Compound	Without	Official committee	1896	19.6850	3.2803	75.0	96.72	124.205	0.0	335.50	21.8919	25,926.20
Compound	With	Vinçotte	1894	25.9842	5.0033	47.87	90.46	300.851	0.0	331.24	12.0372	14,239.18
Compound	With	Vinçotte	1891	31.4960—49.3700	5.9055	51.71	96.72	524.248	0.0	335.50	13.2057	15,639.29
Compound	With	Witz	1892	25.9842—45.2755	4.4291	64.39	89.32	552.577	0.0	330.44	13.3754	15,819.13
Compound	With	Witz	1897	32.0078—55.9841	5.5118	60.905	101.55	779.488	0.0	338.66	12.9411	15,338.43
Triple-expansion	With	Walther-Meunier	1891	20.6692—31.4960—43.3070	4.4291	64.47	82.49	273.304	0.0	325.52	12.5002	14,765.70
Triple-expansion	With	Schroter	1890	19.7342—29.5866—47.3464	4.5981	66.41	147.21	707.868	0.0	364.35	12.4120	14,809.77
WITH SUPERHEATED STEAM.												
Single-cylinder	With	Walther-Meunier	1892	28.0314	4.4849	60.15	64.86	304.638	118.8	430.22	16.2260	19,929.15
Compound	Without	Schroter	1894	12.2047—27.1653	1.6404	117.3	169.25	75.324	289.8	664.56	10.0310	13,744.17
Compound	Without	Witz	1895	3.1496— 5.5118	0.2953	309.7	159.12	6.677	302.4	672.49	12.8970	17,750.18
Compound	With	Gyssling	1893	26.6299—41.3660	4.4291	66.0	92.45	580.507	129.6	462.20	11.1399	14,049.52
Compound	With	Witz	1902	11.8110—19.6850	1.9685	125.3	184.90	147.245	219.6	601.16	12.4120	16,508.94
Compound	With	Walther-Meunier	1898	20.6692—32.4802	3.9370	...	119.47	323.585	305.1	654.65	9.7003	13,304.87
Compound	With	Schroter	1902	12.7952—22.0472	2.7887	127.0	146.21	212.242	310.9	674.75	8.8626	12,226.15
Triple-expansion	With	Walther-Meunier	1897	22.0472—31.4960—45.2755	4.4947	69.98	162.14	804.890	179.1	550.61	10.2956	14,149.94
Triple-expansion	With	Walther-Meunier	1901	19.2913—29.9212—49.2125	4.4291	67.11	157.73	830.228	86.0	455.44	11.0892	13,820.31

power developed by the engines, when superheating is employed. With saturated steam there has certainly been obtained not far from this result, but not with the same sureness of realizing it. Never has there been realized without superheating for an engine of 200 indicated horsepower, an expenditure of only 5,311.8 Fahrenheit units of heat per horsepower per hour. This figure corresponds to a thermal economy of $\frac{5,311.800}{2,508.718}=0.2117$.* Now the writer does not know of any steam engine whose thermal economy exceeds 0.194 for the indicated horsepower.†

Experience shows that, in general, superheating produces appreciable effects in steam engines of all types and of all powers, and that incontestably it increases their economy.

Nevertheless, the question should always be answerable, What is the exact economy obtained by superheating for steam engines of the best design and construction provided with steam jackets and using the steam in multiple cylinders? Is not superheating a superfluity in the case of steam engines in which already nothing has been neglected for preventing the injurious consequences of the interaction of the heat of the steam with the metal of the cylinder? Will the benefit then obtained be a sufficient justification for the use of a costly apparatus subject to rapid destruction, which is and will remain delicate for a long time, and which requires incessant and competent supervision?

To answer this question comparative experiments must be made having for special object the exact determination of the economy realized by the superheating in engines otherwise already excellent. Such experiments have been made

* The thermal economy is the fraction which the units of heat utilized are of the theoretical units of heat equivalent to the work done during the same time. The theoretical equivalent of heat for one horsepower exerted during one hour is $\frac{33,000\times 60}{789.25}=2,508.718$ Fahrenheit units of heat. The divisor is the mechanical equivalent of heat in foot-pounds per unit of heat.—TRANS.

† Gas motors give a much higher economic efficiency. Thus, the Catteau motor with which I recently experimented at Roubaix, consumed 317 liters of gas at 5.784 calories per cubic meter per hour per indicated horsepower. This is an indicated thermic economy of 0.346. It is exceptional, but economies of 0.300 are common, as I have shown in the January and June, 1902, numbers of "L'Eclairage Electrique," in the course of my studies on the comparative economy and functioning of thermic motors.

Table No. 2.—COMPARATIVE CONSUMPTIONS BY THE SAME STEAM ENGINES SUPPLIED FIRST WITH SATURATED STEAM AND AFTERWARDS WITH SUPERHEATED STEAM.

Type of engine.	Experimenters.	Saturated steam.				Superheated steam.					
		Indicated horsepower.	Temperature of the steam, in degrees Fahrenheit.	Consumption per hour per indicated horsepower.		Indicated horsepower.	Temperature of the steam, in degrees Fahrenheit.	Steam superheated, in Fahrenheit degrees.	Consumption per hour per indicated horsepower.		Gain by the superheating, in per centum of the units of heat expended with the saturated steam.
				In lbs. weight of steam.	In Fahr. units of heat.				In lbs. weight of steam.	In Fahr. units of heat.	
Single-cylinder Woolf	Walther-Meunier	357.662	318.29	22.0748	26,025.90	400.122	420.80	102.51	19.5329	24,230.43	6.899
Single-cylinder Corliss	Walther-Meunier	306.019	327.20	19.0501	22,512.65	304.638	430.70	103.50	15.7322	19,568.65	13.077
Compound Corliss	Walther-Meunier	549.665	331.88	18.7393	22,171.67	569.855	446.00	114.12	14.8812	18,774.66	15.321
Compound Corliss	Gyssling	566.570	332.24	14.9032	17,634.54	573.741	462.20	129.96	12.4120	15,654.61	11.228
Triple-expansion Frikart	Weber	689.434	371.62	13.6246	16,285.29	687.846	446.32	74.70	12.0372	14,927.40	8.338
Triple-expansion Corliss	Walther-Meunier	794.162	371.30	12.6722	15,145.69	798.104	550.40	179.10	10.3088	13,428.76	11.336
Compound Van der Kerchove	Schröter	216.029	356.54	12.0593	14,358.55	212.242	665.92	309.38	8.8626	12,097.40	15.748

by various persons, but the Alsatian Association of the Proprietors of Steam Apparatus so ably directed by Mr. Walther-Meunier, has furnished the most of the data for the solution of this important problem: the statement is made with pride that Alsace, after inaugurating the practice of superheating, has also the most effectively contributed to its general introduction and improvement.

The following table, No. 2, shows in parallel columns the results obtained, revolution for revolution, from the same engine with and without superheating, all other things being as near equal as possible.

The gain by superheating varies from 7.8 to 17.3 per centum, and there should be remarked that the order of classification of the engines is the same for saturated steam and for superheated steam, the economy increasing parallel in the two cases, the economy with superheated steam being a maximum for the engine which holds the first rank with saturated steam. The establishment of this fact has a significance which cannot be too much emphasized.

Table No. 3.—PROF. SCHRÖTER'S EXPERIMENTS AT GHENT IN 1902.

.....	Saturated steam.	Superheated steam.				
Temperature in degrees Fahrenheit of the steam.....	356.54	399.74	452.48	506.12	583.52	667.04
Indicated horsepower developed.....	217.89	219.82	220.84	217.27	217.22	212.24
Pounds weight of steam consumed per hour per indicated horsepower.....	12.23	11.73	11.15	10.82	9.97	8.99
Equivalent pounds weight of saturated steam consumed per hour per indicated horsepower.....	.....	11.94	11.60	11.49	10.89	10.10
Corresponding Fahrenheit units of heat consumed.....	14,557	14,219	13,800	13,668	12,955	12,038
Economy realized by the superheating, in per centum...	.....	2.4	5.1	6.0	11.0	17.3

The experiments on the last line in the table deserves in other respects to arrest attention. They form part of an important series made by Professor Schröter in September, 1902,

in Ghent at the van den Kerchore shops on an engine with piston valves of which the small cylinder was without steam-jackets. These researches show the influence of a progressive superheating.

These experiments have been followed by others made with much higher degrees of temperature, and the economy obtained confirm the brilliant results that have just been described.

From an inedited memoir most obligingly communicated, the following experimental results are extracted.

Table No. 4.—INEDITED EXPERIMENTS COMMUNICATED TO THE AUTHOR.

.....	Saturated steam.	Superheated steam.			
Pressure of the steam in pounds per square inch above the atmosphere..	129.29	129.86	130.57	131.42	130.00
Corresponding temperature of the steam in Fahrenheit degrees.....	357.24	357.55	357.98	358.39	357.76
Temperature in Fahrenheit degrees of the steam at the small cylinder..	352.45	490.46	584.24	647.42	734.00
Superheating in Fahrenheit degrees..	.....	132.91	226.26	289.03	376.24
Indicated horsepower developed.....	224.63	230.42	228.87	220.42	218.58
Pounds weight of steam consumed per hour per indicated horsepower	12.92	10.89	9.79	9.41	8.61
Fahrenheit units of heat consumed per hour per indicated horsepower	15,361	13,660	12,722	12,678	11,805

The temperature of 758.48 degrees Fahrenheit has even been attained, or 400.5 Fahrenheit degrees of superheat, and the consumption of steam has fallen to 8 pounds, corresponding to 11,071.56 Fahrenheit units of heat. Consequently, the maximum has not been at all reached, and the experiment shows decisively that still more economic gain could have been obtained had higher superheating been possible. Much importance can be attached to this experimental proof.

The law which M. Walther-Meunier announced in 1895 is thus solidly established, namely, that the consumption of heat per hour per indicated horsepower diminishes in measure as the temperature of the superheat increases, and the economy is continuously increased.

M. Dujardin, in another direction, has deduced from experi-

ments he has made on his workshop engine that, with variable engine load, the consumption of superheated steam remains constant per unit of power developed at both full power and at half power. The following quantities are decisive in this respect.

DUJARDIN'S EXPERIMENTS MADE TO DETERMINE THE INFLUENCE OF VARIABLE DEVELOPMENTS OF POWER UPON THE ECONOMY OF SUPERHEATING.

Pressure of the superheated steam, pounds per square inch above the atmosphere	85.337	125.161	99.560	71.114	85.337	103.826
Indicated horsepower developed	88.767	136.109	137.096	163.726	170.630	202.191
Temperature in degrees Fahr. of the superheated steam	509.000	550.400	527.000	518.000	518.000	545.000
Temperature in degrees Fahr. of the saturated steam	327.600	352.770	337.370	316.690	327.600	340.115
Number of degrees Fahr. of superheat	181.400	197.630	189.630	201.310	190.400	204.885
Pounds weight of steam consumed per hour per indicated horsepower	13.523	13.232	13.411	13.300	13.300	13.255

The experimental data now possessed in regard to superheating can, consequently, be summarized in the following laws:

1st. Superheating increases the economy of steam engines of all types; single cylinder, Woolf compound or triple expansion, even when they are provided with steam jackets applied under the best conditions.

2d. The economy increases with the number of degrees of superheating.

3d. The consumption per hour per indicated horsepower developed by the engine remains constant for full power and for half power.

Such are the facts that theory ought to explain.

A general consideration of the cycle of the steam engine shows in the first place that raising the temperature of the

steam above the saturation point would necessarily improve the economy.

The cycle of the steam engine does not respond to Carnot's concept, notwithstanding that the heat is imparted to the water by the furnace at the constant temperature which call T_1, after which it is reduced to the constant temperature T_2 by the condenser, which thus performs the office of refrigerant, the cycle of the steam engine is not the cycle of Carnot because it is not limited by two adiabatics. The fourth phase of the theoretical cycle, namely, that of comparison without either gain or loss of heat, and which ought to return the fluid to its initial state, is absolutely in default in the real cycle of the steam engine, for instead of returning at the temperature T_1 the mixture of steam and water remains in the condenser at the temperature T_2. That the cycle closes can be admitted, but it is not a reversible cycle. The case would then be known not to be a question of applying the formula of Carnot $\frac{T_1 - T_2}{T_1} = 1 - \frac{T_2}{T_1}$; there should always be observed, however, that to make this final compression would not be impossible, and to thus reintroduce into the boiler water at the temperature T_1; some English engineers have attempted it, and not without some success, and if they have renounced it, it is because they have shown that the solution of this problem has not a sufficient practical interest. We have then some right to still use the theoretical formula for remote approximations, and to retain for general indication the conclusions to which it leads; among them is the economic advantage of increasing the fall of temperature $T_1 - T_2$ by increasing T_1; now this is done by superheating the steam.

Having regard to the above reserves, let the value of the economy, which call ρ, be calculated for the case when the saturated steam has the temperature 327.2 degrees Fahrenheit (for 85.337 pounds per square inch above the atmosphere), and that of 495 and 666 degrees Fahrenheit of superheat, the condenser having the temperature 86 degrees Fahrenheit.

$T_1 = 459.4° + 327.2° = 786.6°$ Fahr. absolute.
$T_1 = 459.4° + 527.0° = 986.4°$ Fahr. absolute.
$T_1'' = 459.4° + 698.0° = 1{,}157.4°$ Fahr. absolute.
$T_2 = 459.4° + 86.0° = 545.4°$ Fahr. absolute.

$T_1 - T_2 = 241.2°$ $\qquad \rho = 1 - \frac{545.4}{786.6} = 0.306$

$T_1 - T_2 = 441.0°$ $\qquad \rho = 1 - \frac{545.4}{986.4} = 0.447$

$T_1'' - T_2 = 698.0°$ $\qquad \rho = 1 - \frac{545.4}{1{,}157.4} = 0.529$

Progressive superheating increases progressively the economy, and it could give in a steam engine functioning according to the cycle of Carnot an economy of 67 per centum for a superheat of 630 Fahrenheit degrees. The real machine is very far from realizing anything like this.

Let us see what we ought really to gain by superheating.

The economy of any cycle whatever can be calculated rigorously, provided that it be a closed cycle, by making it the quotient of the division of the heat transmuted into work by the heat obtained from the furnace, that is to say, by the aid of the formula $\frac{Q_1 - Q_2}{Q_1}$, Q_1 being the heat obtained from the furnace, and Q_2 being the heat carried to the refrigerant.

Now, we have the means of calculating exactly Q_1 and Q_2.

Suppose the cycle to be traversed by a mixture of one pound weight of steam and water.

This pound is delivered into the condenser in the liquid state at the temperature t_2,* and from the condenser it is pumped into the boiler where the water is raised from the temperature t_2 to the temperature t_1 and vaporized. But the saturated steam is not, generally, furnished in the dry state to the cylinder, which receives a mixture of steam and water containing a fraction x_1 of steam and a fraction $i - x_1$ of water.

This mixture carries with it the quantity of heat equal to

* The letters t designate thermometric temperatures, and the letters T designate absolute temperatures.

$\int_{12}^{11} C dt + x_1 r_1$; C is the specific heat of the water, and r is the heat of its vaporization at the temperature t_1; if C be assumed to be constant,

$$Q_1 = C(t_1 - t_2) + x_1 r_1.$$

This mixture acts upon the piston, first at full pressure, then it expands, passing from the pressure ρ_1 in the boiler to the pressure ρ_2 in the condenser, and from the corresponding temperature t_1 in the boiler to the corresponding temperature ρ_2 in the condenser. Clausius and Hirn discovered that this expansion is fatally accompanied by a partial liquefaction which lowers the composition of the mixture from x_1 to x_2. Clausius demonstrated that x_2 is determined in function of x_1 by the formula

$$\int_{T_2}^{T_1} C \frac{dT}{T} + \frac{x_1 r_1}{T_1} - \frac{x_2 r_2}{T_2} = 0.$$

The value of x_2 is then known.

The condenser liquefies the whole of the mixture; consequently $x_2 r_2$ is retired; it is the quantity Q_2.*

We have therefore:

$$\rho = \frac{Q_1 - Q_2}{Q_1} = \frac{C(t_1 - t_2) + x_1 r_1 - x_2 r_2}{C(t_1 - t_2) + x_1 r_1} = 1 - \frac{x_2 r_2}{C(t_1 - t_2) + x_1 r_1}.$$

In this manner is calculated the economic performance ρ of a steam engine supplied with saturated steam of the composition x_1.

In the case of superheating $x_1 = 1$; further, the superheating costs in heat $C(t_1' - t_1)$, C being the specific heat, supposed constant, of the steam, and t_1' the temperature of the superheating.

We have, then:

$$Q_1 = C(t^1 - t_2) + c(t'_1 - t_1) + r_1.$$

*The two terms $A\rho_2$, ux_2, which cancel, are not mentioned; on the other hand, the work is neglected of feeding the boiler, which is the same for saturated and for superheated steam, and is, moreover very small.

In expansion, the steam gradually loses its superheating and passes to saturation, ending, finally, with a composition that may be called x'_2 to distinguish it from x_2; x'_2 is evidently greater than x_2.

The rest of the calculation is identical with the preceding.*

We have, then:

$$\rho = 1 - \frac{x'_2 r_2}{C(t_1 - t_2) + c(t'_1 - t_1) + r_1}.$$

To render account of the effect produced by the superheating, the respective values of ρ and ρ' must be determined for a concrete example; for this purpose, replace the symbols by the numbers below given.

$$t_1 = 327.2° \text{ Fahr.} \quad t_2 = 86° \text{ Fahr.} \quad t_1 - t_2 = 241.2° \text{ Fahr.}$$
$$r_1 = 883.19 \qquad r_2 = 1054.12$$
$$C = 1.013$$

Take $x_1 = 0.95$, the value habitually assumed; the formula of Clausius gives $x_2 = 0.79$.

All calculations being made, there results from the processes of saturated steam:

$$\rho = 1 - 0.768 = 0.232.$$

In superheating, $t_1 = 662°$, $c = 0.48$, $x'_2 = 0.248$.

The gain is then equal to about 7 per centum.†

Before discussing that result, the observation can be made that the calculations furnish a most valuable indication; they show that in an expansion from the pressure corresponding to the saturation temperature of 327.2 Fahrenheit degrees to the pressure in the condenser corresponding to the saturation temperature of 86 Fahrenheit degrees, even when accompanied by a superheating to 662 Fahrenheit degrees, the

* In the calculations no account is taken of the action of the steam jacket, the heat from which contributes, in a certain measure, to lessen the liquefaction in the cylinder.

† Regnault adopted for the specific heat c of superheated steam, the constant value 0.48, which is employed in our calculations; but this coefficient very probably increases with the temperature, and that at 662 Fahrenheit degrees it should be much greater, thereby largely increasing the economy.

steam loses its entire superheating, and its composition falls to 0.92. This does not happen in the case of a less complete expansion. Thus, I have established for an engine using its steam without condensation, and with superheating to 689 Fahrenheit degrees, exhausting into the atmosphere at the temperature 244.4 Fahrenheit degrees*; that the phenomenon would be less marked in practice, because the steam is rarely expanded to the pressure in the condenser; nevertheless, there can be said that the superheating ordinarily given is insufficient to remain to the end of the stroke of the piston. To obtain such a result the superheating would have to be carried much higher than 662 Fahrenheit degrees.

What is this exact temperature?

Thermodynamics can furnish an answer to this question.

Clausius asserts that superheated steam expands like a gas, and that the formula of Poisson, $pv^{\gamma} = \text{constant}$, is applicable to it, provided the exposant γ be made equal to 1.28; from which results that the absolute temperatures and the corresponding pressures are related as expressed in the known formula:

$$\frac{T_1'}{T_2} = \left(\frac{p_1}{p_2}\right)^{\frac{\gamma-}{\gamma}}.$$

Substituting centigrade numbers, there are found:

$$T_1' = 303 \left(\frac{7}{0.0429}\right)^{0.218} = 920^{\circ} \text{ absolute} = 647^{\circ} \text{ centigrade.}$$

In a steam engine using the steam with condensation and with complete expansion, and without having regard to the action of the steam jacket, for the steam to reach the end of the stroke of the piston in an absolutely dry state would require a superheating to above 1,100 Fahrenheit degrees. The latest experiments may perhaps realize such a temperature; if they do, they are to be congratulated because, in that case,

* The experiment was made on a small Buffaud and Robatell engine furnished with steam from a Serpollet superheating boiler. I experimented with this engine at Paris in 1896; it consumed 13.15 pounds weight of steam per hour per indicated horsepower, under a pressure of 100 pounds per square inch above the atmosphere.

the value ρ of the economy would receive a remarkable increase, inasmuch as the calculation then gives

$$\rho = 0.375,$$

and the economy of the gas engine would be surpassed.

It is absolutely true that at the present time the case which has just been considered is wholly fictive and merely theoretical, but the advocates of steam will, without doubt, remember the deductions made from our calculations. Others will be content to note that the theory is in accord with practice, because there has been experimentally shown that a continually increasing economy results from a continually increasing superheating up to at least 750 Fahrenheit degrees.

But they will also remark that the economy promised by calculation has been less than that which has been experimentally realized. This fact is interesting because speculative calculations, such as those which have just been made, ought to give results greater than those furnished by experiment, because they apply to only perfect machines free of wastage.

How does it happen that while the calculations predict only 7 per centum of economy, 18 per centum are often experimentally obtained?

Are the calculations false, or are they incomplete?

We shall see that they are incomplete.

Hirn had, in fact, already encountered similar divergences between theories and facts, and he had been led in a manner to declare that all those theories which he called *generic* were insufficient, because they omitted a capital element in the question, namely, *the interaction of the metal of the cylinder with the heat of the steam.*

There remains, then, for us to include in the study of the phenomena which take place within the cylinder this preponderating influence of the metal in contact with which the steam evolves in its cycle, in applying the experimental theory of the master.*

* Witz. De l'effet thermique des parois d'une enciente sur les gaz qu'elle renferme: Thèse inaugurale soutenue devant la Faculté des Sciences de Paris, et Annales de chimie et de physique. 5e série. Tome XV. 1879.

The superheating of steam has for first effect, the transformation of an immediately condensable fluid into a gas capable of parting with a considerable quantity of its heat without liquefying; and I demonstrated in 1878, that the non-liquefiable gas lost less of its heat by its contact with the metal of the cylinder which enclosed it, than liquefiable vapors lost under the same circumstances: the action of the metal of the cylinder is then less on the superheated steam than on the saturated steam, and the expansion the more closely approximates the adiabatic state.

But this is the small side of the question, for there is another consideration still more decisive, and another influence still more energetic. When the steam has arrived in the state of saturation at the end of its expansion, it has deposited a fine dew on the interior surfaces of the cylinder; this dew vaporizes at the moment the cylinder is put in communication with the condenser, taking the necessary heat for this purpose from the metal of the cylinder, and this phenomenon occasions the loss which Hirn called *the cooling by the condenser*. This is the loss which most contributes to the lessening of the economy of the steam engine. "The most disastrous cause of the loss of heat," said Hirn, "is the instantaneous vaporization of the water which remains on the metallic inner surfaces of the cylinder at the end of the expansion, and at the moment of the exhaust to the condenser."*

This vaporization has for immediate result so great a cooling of the metal that it produces at the beginning of the following cycle, during the consecutive admission, an abundant liquefaction of steam, which lowers the composition of the freshly-admitted steam, wets again the inner surfaces of the cylinder, and aggravates the evil until the regimen is established. These phenomena constitute the gravest cause of the deterioration of the cycle; the quantity of heat lost in this manner can much exceed the quantity of heat transmuted into work.

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*Hirn. Exposition analytique et experimentale de la Theorie mechanique de la chaleur. 3d edition. Tome II, page 65. Paris. 1875.

Now, it is evident that this deterioration is so much the more important as x_2 is more feeble; it is greatly reduced by the superheating, since x'_2 is always greater than x_2.

But this is not all: if the superheating of the admitted steam be such that $(t'_1 - t_1)$ is greater than the cooling to the condenser, the steam will not liquefy during the period of admission, from which will, consequently, result a considerable economy entirely neglected by the generic theory, which to that extent is incomplete.

We can thus understand why the calculation gives only 7 per centum of economy, while experiment sometimes gives 17 per centum.

The constancy of the consumption of superheated steam, found at half power and at full power, is explained by the same considerations; the saturated steam x_2 is so much the more feeble as the expansion is more nearly complete, and its value ought to diminish with the power developed; this is why the consumption at half power is always greater than at full power. But when the steam is superheated the variation of x'_2 is much less marked, and economy varies only insensibly.

Since x'_2 is never equal to 1, by default of sufficient superheating, the employment at the same time of steam jacketing and of multiple expanding will consequently remain useful; superheating should then always be economical for all steam engines under all conditions, as practice has demonstrated it to be.

But its effect is not much in the small cylinder of compound- and triple-expansion steam engines, the internal liquefaction being produced chiefly in the following cylinders. It would then be rational to superheat the steam in the *receivers* during its passage from a preceding to a succeeding cylinder, as proposed by the Messieurs Sulzer, and which seems to have been successfully done in Germany.

The experimental theory completing the conclusions derived from the generic theory sufficiently accounts for the different particularities observed in the processes of superheating, and explains the economy realized, which results from the greater

fall of temperature between the boiler and the condenser, from the best conditions for the expansion and, principally, from the diminution, if not the complete suppression, of the cooling to the condenser.

These considerations are of a nature to encourage practical engineers to continue their experiments and to persevere in their attempts; the great object is to perfect the superheaters, and to construct engines that allow the use of high temperatures without losing their certainty in functioning, which is the most important quality in steam engines. The ablest engineers are now engaged on this task, and there is hope they may succeed.

Meanwhile, all users of steam power are interested henceforth in adding superheaters to their boilers, and a very moderate degree of superheating will suffice to produce appreciably good results with any kind of steam engine.

NOTE BY TRANSLATOR.

The experiments in the Author's Table No. 1, can hardly be considered as comparative, though very interesting in many respects. Such experiments to be comparative, should be described in greater detail and the data should be complete. Moreover, in the cases of using saturated and superheated steams, several of the conditions, especially, should be the same or very nearly the same, namely, the pressure of the steam, the number of double strokes made by the pistons per minute, the measure of the expansion with which the steam is used, and the temperature of the feed water. Of course the type of engine should be the same, and the steam jacketing should be the same. No statement is given as to whether the cylinders were steam jacketed or not, nor with what measure of expansion the steam was used. The temperature of the feed water is not stated, and the calculation of the results from the heat consumed had to be made on the supposition that in all cases this temperature was 32 degrees Fahrenheit.

The importance of the knowledge of all the facts of the experiments may be estimated by the following economic effects depending on them :

The loss of steam by leakage past the valves and pistons of the cylinders varies with the pressure of the steam in them, other things being equal. The greater this pressure the greater this loss, which latter is a considerable item with all steam engines. Then, on the contrary, the greater the initial pressure in the cylinders, other things equal, the greater will be the ratio of the mean utilized pressure to the mean total pressure, the latter being measured down to the zero of pressure ; the non-utilized pressure being the sum of the mean back pressure against the piston and of the pressures due to the two kinds of friction opposing the movement of the piston ; that is to say, the sum of the pressure required to equilibrate the friction of the moving parts of the unloaded engine and the friction of the load, the latter being as the load, while the former is as the weight of the moving parts of the engine. Both these frictions are measured in the mean indicated pressure on the piston, as shown by the indicator-diagram. As the greater the initial steam pressure in the cylinder the greater the economic loss by leakage and, also, the greater the economic gain by the greater fraction of the total pressure utilized, this loss and this gain, both due to higher pressure, may be considered, in measure, to offset each other. Also, the higher the steam pressure the greater the economic loss by the external radiation of heat. And, finally, as the greater the initial pressure in the cylinder the more expansively the steam can be used, with the corresponding economic gain, but with the inevitably accompanying economic loss due to the increasing interaction of the heat of the steam with the metal of the cylinder as the expansion increases ; the gain and the loss thus produced may also be taken in measure to offset each other.

All practical experience, however, shows that increased reciprocating speed of piston and increased pressure of steam, either separately or combined, are factors of value in the pro-

duction of economic efficiency in the case of steam engines, independently of other conditions, and that for the determination of comparative economic results effected by other conditions, equality in these particulars is essential.

The use of Table No. 1 for the purpose for which it is given, namely, the comparison between the economy obtained from saturated and from superheated steam, in order to show the gain by the latter, the comparison in question must be limited to the mean data of the experiments made with multiple-cylinder engines using the steam with condensation, and having steam jackets in both cases. This limitation reduces the comparison to the mean of the last five experiments made with saturated steam, and to the mean of the last six experiments made with superheated steam, with the exception of the experiment in which the items were not complete.

MEAN DATA OF FIVE EXPERIMENTS WITH SATURATED STEAM.

Number of double strokes made by the pistons per minute.....	61.577
Pressure of steam, in pounds per square inch above atmosphere..	103.46
Indicated horsepower developed by engine.....	567.497
Temperature, in Fahrenheit degrees, of the saturated steam.....	338.89
Pounds weight of steam consumed per hour per indicated horse-power.....	12.8869
Fahrenheit units of heat consumed per hour per indicated horse-power.....	15,274.46

MEAN DATA OF FIVE EXPERIMENTS WITH SUPERHEATED STEAM.

Number of double strokes made by the pistons per minute.....	91.080
Pressure of steam, in pounds per square inch above atmosphere..	148.69
Indicated horsepower developed by engine.....	515.022
Number of Fahrenheit degrees that the steam was superheated..	220.14
Temperature in Fahrenheit degrees of the superheated steam....	548.83
Pounds weight of steam consumed per hour per indicated horse-power.....	10.7599
Fahrenheit units of heat consumed per hour per indicated horse-power.....	14,150.97

ECONOMIC RESULTS.

The economic gain due to the superheating was, according to the above comparison,

$$\left(\frac{15,274.46 - 14,150.97 \times 100}{15,274.46} =\right) 7.355 \text{ per centum}$$

in function of heat expended for the production of equal power.

If the steam jackets be supposed to have wholly prevented "cylinder condensation," and if the difference of the conditions of the experiments with saturated steam and with superheated steam be considered to have had no economic influence on the result, then this gain of 7.355 per centum was due to the superior economy obtained by the experimental amount of superheating, namely, 220.14 Fahrenheit degrees imparted to saturated steam of the pressure of 148.69 pounds per square inch above the atmosphere, over the economy obtained with saturated steam alone, the expenditure of heat being the same in both cases. In other words, under the particular conditions of the experiments the same quantity of heat expended in the two cases gave 7.355 per centum more power when superheated than when saturated, showing an economic superiority of that much for superheating alone. But this amount of economic gain applies only to these particular experiments, and cannot be predicted as true for comparative results obtained under other conditions.

The number of Fahrenheit units of heat equivalent to one horsepower exerted during one hour, the mechanical equivalent of heat being taken at 789.25 foot-pounds per unit of heat, is $(33{,}000 \times 60 \div 789.25 =)$ 2,508.72. The Fahrenheit units of heat consumed per hour per indicated horsepower when saturated steam was used was 15,274.46, consequently in this case $(15{,}274.46 \div 2{,}508.72 =)$ 6.088 times the academic quantity of heat was practically used, or $(100 \div 6.088 =)$ 16.426 per centum of the heat consumed was converted into indicated work, which is about the average economic result given by steam-jacketed, multiple-cylinder condensing engines.

Proceeding in the same manner for the case when superheated steam was used, there results that of the heat practically expended, 17.730 per centum was converted into indicated work.

In these comparative experiments, the economic effect produced by the considerable superheating given to the steam

appears small, certainly it could not have been less than the 7·355 per centum obtained; assuming the experimental data to be correct, and there is no reason to doubt it, then the differences that existed between the conditions when saturated steam and when superheated steam were used must, as regards the final economy, have such compensations in the matter of gain and loss as to practically neutralize them, causing the economic results to be the same as though these economic conditions were alike in both cases; a very interesting and not at all improbable conclusion. The experimental gain must be distinctly understood as applicable only to the exact conditions existing during the experiments, and cannot be assumed as what would be obtained under other conditions.

Although the first series of experiments were made with strictly saturated steam, yet they had the benefit of whatever gain was due to the steam jacketing.

The last series of experiments were made with superheated steam, but they, too, had the benefit of whatever gain was due to the steam jacketing.

Consequently, the results of the comparison is really the gain which the superheating effected above the gain due to the steam jacketing. These results are, therefore, considerably different from what they would have been had there been no steam jacketing in either case.

The economic effect of properly applied steam jacketing is the prevention of "cylinder condensation." Now, this prevention constitutes a large part of the economic benefit of superheating, which is correspondingly lessened by its prevention, thus leaving only the benefit due to the superheating really as such. Moreover, although the superheating apparatus was placed between the boiler and the chimney, and the steam was superheated by the waste heat in the chimney gases, yet that heat was computed and charged to the cost of the power. Both of these processes made the economic result of the superheating less than it would have been had there been no steam jacketing in either case, and had no charge

been made of the waste heat in the chimney gases utilized for the superheating.

The superheating surface was placed between the boiler proper and the chimney, so that the superheating was done by waste heat from the boiler after the hot gases of combustion had left it, in which case the practical economic gain, as distinguished from the academic economic gain due to the superheating, would have to be ascertained from very different factors than in the foregoing comparison.

The heat expended in the superheating of the steam has been calculated as the product of the difference of the temperatures which the steam had between the beginning and the end of the superheating, into the pounds' weight of steam superheated per hour, into 0.6, which fraction is assumed in the absence of exact determinations, as the specific heat of superheated steam under constant pressure, and constant for all temperatures. Any error due to the uncertainty of this fraction will be very small. This superheating heat has, in the preceding comparison, been added to the heat of the steam normal to the pressure of the superheated steam, the sum of the two being taken as the cost in heat of producing the superheated steam. But, practically, when the superheating is done by waste heat escaping from the boiler this superheating heat should not be added, and the comparison of the economic results should be made by taking for the heat-cost of producing the two steams only the heat of the generation of the saturated steam.

In the case of the superheated steam in the previously given comparative data, of the 14,150.97 Fahrenheit units of heat consumed per hour per indicated horsepower developed by the engines ($220.14 \times 0.6 \times 10.7599 =$) 1,421.21 Fahrenheit units of heat were contributed by the superheating done in the superheater, the remaining ($14,150.97 - 1,421.21 =$) 12,729.76 Fahrenheit units of heat being contributed by the vaporization of water in the boiler.

In the case of the saturated steam in the previously given comparative data there were consumed per hour per indicated

horsepower developed by the engines 15,274.46 Fahrenheit units of heat.

Consequently, the indicated horsepower cost in the case of the superheated steam $\left(\frac{15{,}274.46 - 12{,}729.76 \times 100}{15{,}274.46} =\right)$ 16.66 per centum less than in the case of the saturated steam, which, as this percentage represents the gain in fuel consumed, may be taken as the commercial value of the superheating as done. Of course, $(16.66 - 7.355 =)$ 9.305 of the 16.66 per centum of gain was due not to the superheating but to the use of heat that would have otherwise been wasted.

When experiments in progressive steam-superheating are made on the same steam engine developing the same constant number of horsepowers with steam of the same pressure, and with all other conditions the same except the degree to which the steam is superheated, the weight of water vaporized in the boiler, per horsepower developed by the engine, decreases in the proportion in which the superheating increases. This is due to the fact that the same pressure being preserved, the more of the work done by the superheat of the steam, the less must be the work done by the generation of the steam, the sum of the two being a constant. Consequently, superheating the steam does not increase the power of the same engine doing the same work in the same time, but it increases the economy with which that work is done.

Among the advantages of superheating not mentioned by the author, should be included the saving effected by it in the first money cost and in the repairs afterwards, and in the sinking fund, of the boiler; equal quantities of steam of equal pressure and better quality being furnished by it in equal time. This saving would be about one-sixth, as determined by the experimental data, in which case the superheating was done by waste heat in the chimney gases. For marine purposes, the lessening of the boiler by one-sixth, its development of power remaining the same, is a very serious gain otherwise, as it saves one-sixth of the weight and volume of the boiler in the vessel. Further, one-sixth of the weight and

volume of the coal required for equal distances traversed by the vessel in equal time, would also be saved. The author insists only on the heat saving effected by superheating per unit of power developed, which, indeed, is the great point of interest with land boilers, and they are the special objects of his investigations; but the gain obtained by superheating is really of much more importance for marine boilers, as has been just pointed out, and the field is nearly as wide. Of course, from the space and weight saved in the boiler alone, there must be deducted the weight and space of the added superheating apparatus, but for the saving in the weight and space of coal carried, no deductions are to be made. The money cost, however, of the superheating apparatus must be deducted from the cost of the part of the boiler saved by it.

The comparison for weight must be when the superheating apparatus is not used, the aggregate weight of boiler including its contained water and the weight of the coal required; and when the superheating apparatus is used, the aggregate weight of boiler, including its contained water, the weight of the superheating apparatus and the weight of the coal required. The comparison for space must be made on the same basis.

The comparison for money cost must be made simply for the boiler alone when the superheating apparatus is not used, and for the aggregate boiler and superheating apparatus when the latter is used.

Additionally, there must be considered the money value for cargo purposes of the space and weight saved in the vessel. And, also, the money value of the coal saved for all the steaming done by the vessel during the life of the superheating apparatus.

As the temperature of the chimney gases is usually high enough to give as great a degree of superheating as can safely be permitted in average practice and under ordinary supervision, the heat in those gases, and which would otherwise be lost, should be utilized, instead of employing a superheater with an independent furnace, and a specific consumption of coal to produce the superheating.

It is quite true that the addition of the heat-absorbing surface of the superheater to the water-heating surface of the boiler would utilize a part of the waste heat escaping in the chimney gases by evaporating more saturated steam; but the economy obtained would not be as great, and for two reasons: 1st. To produce a given pressure, more heat must be imparted to the water for the generation of saturated steam than is required for the superheating of this steam. 2d. When taken in connection with the steam engine, the given volume of saturated steam of given pressure could not develop as much power as would be obtained from the superheated steam, because the steam produced in the first case would be saturated steam which would partially liquefy on the slightest abstraction of heat, while the superheated steam could, without any liquefaction, be reduced in temperature by the abstraction of heat until the whole superheat had been taken out.

The use of sufficiently superheated steam, therefore, prevents liquefaction in the cylinder and the economic loss attending it; for as long as the temperature of the steam in the cylinder is above the saturation temperature, there cannot be any "cylinder condensation." Now, whatever water of liquefaction may be deposited on the inner surfaces of the cylinder, the same has to be revaporized by heat taken out of the metal of the cylinder, which heat in turn has to be restored during the next stroke of the piston by latent heat taken out of the steam entering the cylinder from the boiler, consequently, the whole of this heat is lost for the production of power.

From the foregoing appears that superheating the steam causes two entirely distinct economic effects in the steam engine; one, negatively, as a preventive of a loss ("cylinder condensation"); the other, positively, as a productive of gain (the greater external work done by a given quantity of heat in the expansion of the gas superheated steam than in the expansion of water into saturated steam); but the two are only necessarily combined when saturated steam is used in the cylinder.

Suppose the cylinder to be efficiently steam jacketed (which can always be effected by filling the jacket with saturated steam of higher pressure than the saturated steam which enters the cylinder), so that a sufficient additional quantity of heat be passed from the steam in the jacket into the steam in the cylinder to maintain the latter steam above the saturation temperature, then superheated steam from a superheater could not act preventively by suppressing "cylinder condensation," as this would have been done already; consequently, this source of gain could not, in such a case, be credited to the superheated steam drawn from the superheater. But this latter steam would still produce the economic gain due to the greater power effect of superheated steam over saturated steam caused by the fact that substantially the whole of the superheat is sensible heat and does external work, while in the case of saturated steam a large portion of the heat becomes latent during the conversion of water into steam.

"Cylinder condensation" is wholly due to, and is in proportion to, the use of saturated steam expansively, and by reason of the continuous fall in the pressure and, consequently, in the temperature of the expanding steam; this fall of temperature making possible the interaction between the heat in the expanding steam and the metal of the cylinder with which that steam is in contact, whereby the heat taken out of the metal at one time by the expanding steam has to be replaced in the metal at another time by heat taken out of the entering boiler steam; the process occurring through the intermediary of the liquefying of the saturated steam and the revaporizing of the water of that liquefaction. The economic loss by the process consisting of the latent heat of the reevaporated steam, which passes into the condenser without doing external work.

If saturated steam were not used expansively, there would not be any "cylinder condensation," supposing no radiation of heat from the external surfaces of the cylinder and no "working over" of water from the boiler.

The purpose of steam jacketing is to add heat taken out of

its steam to the expanding steam in the cylinder, thereby preventing partial liquefaction of this latter steam and the consequent economic loss due to the revaporization of the water of liquefaction, the steam of which passes into the cylinder without doing external work.

The author has entirely ignored the serious loss in all steam engines by leakage of steam past the valves and piston of the cylinder. He attributes the difference between the weight of steam present as such in the cylinder at the closing of the cut-off valve as shown by the indicator, and the weight of steam drawn from the surface condenser per stroke of piston, wholly to what is termed "cylinder condensation," while, in fact, this difference is the sum of the leakage referred to and of the liquefaction due to the interaction between the metal of the cylinder and the heat of the steam, technically known as "cylinder condensation." The proportion of leakage does not admit of calculation, as it is due to imperfect workmanship and to the distorting action of the temperature of the steam upon the organs mentioned of the cylinder; besides which, it is mainly a steady "blow-through" from valve chest to condenser without interruption so that it is relatively less with greater reciprocating speed of piston. The proof of this leakage is the universally-recognized fact that the greater the number of double strokes made by the piston in a given time, the greater the economy with which the power is developed, other things remaining the same. In other words, the greater the number of double strokes made by the piston per unit of time the greater in direct ratio will be the power developed, while, as the leakage is sensibly constant per unit of time, it will *proportionally* affect the economy because there will be a larger and larger power to distribute the constant leakage among. If the engine functioned absolutely without leakage, the economy of its performance would not be affected by the reciprocating speed of its piston.

As a general fact the sum of the leakage and of the "cylinder condensation" may be taken for an example at, say, 21

per centum of the water of liquefaction drawn from the condenser, and of this 21 per centum at least one-third is probably leakage, leaving 14 per centum for the "cylinder condensation"; the loss of heat by the latter would then be the product of the number of pounds of water corresponding to this 14 per centum by the latent heat of the steam in the boiler.

Suppose the "cylinder condensation" to be 14 per centum of the water of liquefaction drawn from the surface condenser, then an economy of 14 per centum would be roundly the utmost that could be obtained by an amount of superheating just sufficient to prevent it, the superheating being done by heat taken from the hot gases of combustion in the chimney. If the superheating be done by an independent furnace the weight of coal consumed for that purpose in this furnace must be added to the weight of coal consumed in the boiler for the generation of the steam. The proper comparative commercial measurements now become the *aggregate* weights of coal consumed in boiler and in superheating furnace when the steam is superheated in that manner, and the coal consumed in the boiler alone when there is no superheating. The quotients of the division of the respective external work done by the engine, into these two quantities of coal, expresses the relative economy obtained by the superheating.

A comparison of the respective *units of heat* consumed in these two cases will give the relative economy as regards number of heat-units used, but not as regards the weights of coal required, to experimentally produce them; for, evidently, in the case of superheating by a separate furnace there would have to be burned the coal in the separate furnace required to produce the superheating, while, if the superheating be done by otherwise waste heat in the chimney-gases no additional coal would be required for that purpose, and whatever additional power might thus be obtained would appear to have been had for nothing.

If, however, the purpose be to obtain a higher superheating temperature than the chimney-gases can supply, then the independent superheating furnace with its specific additional

consumption of coal is a necessity; but the question arises whether the less superheating done by the chimney-gases without special expenditure of coal for the purpose is not economically equal to the greater superheating obtained in the independent furnace by the direct expenditure of the additional coal required to produce it?

The highest limit of temperature which the metal and the organs of the engine and of the superheating apparatus can bear without injury under the worst circumstances to which they will be subjected during prolonged use, and the mean temperature of the gases in the chimney, which varies for different conditions, but within comparatively narrow limits, are the two factors of the answer to the foregoing question. The limit of temperature referred to is soon reached, and beyond that limit the investigation of the economy due to still higher degrees of superheating becomes merely academic.

The results of short experiments made under carefully prepared conditions, and under the supervision of competent experts, cannot be accepted for prolonged service under the conditions that must be met in average practice.

Within reasonable limits of superheating, the heat for that purpose being taken without cost from the waste heat in the chimney gases, the use of superheated steam gives an economic gain which should never be neglected, especially as the superheat will never be sufficiently great to endanger the integrity of the machinery. The translator makes this affirmation as the invariable result of his own very great practice in this direction with an extensive variety of superheating apparatus. In his designs the temperature of the superheated steam was always kept well below temperatures prejudicial to either superheater or engine. He was content with moderate gains, and always kept in view that reliability was the first virtue of a steam engine whether on land or sea. He never had an accident with any of his superheaters, and all performed in a satisfactory manner.

THE ENGINEERING SITUATION IN THE UNITED STATES NAVY.

By Lieutenant Henry Charles Dinger, U. S. Navy, Member.

It has been my endeavor in writing this article to place before my readers a general description of the actual engineering conditions in the U. S. Navy; and, from this standpoint, to explain remedies that appear necessary, desirable and adequate to cope with present deficiencies, as well as, if possible, to call attention to certain threatening conditions that seem to be largely overlooked, and to strengthen the warning cry against various proposed plans of remedy which are not based on sound principles. Little is accurately known by the general public interested in naval matters of the present engineering conditions in the Navy, though the subject is continually being commented upon. Newspaper articles, reports and editorials are appearing unceasingly, ardently discussing present and past conditions, advocating some remedies and criticizing others that are proposed. Recommendations more or less antagonistic to each other are also appearing from various authoritative sources in the Navy.

Such an amount of criticism and discussion alone must impress the interested observer with the fact that there must be something wrong somewhere; but if the seeker after knowledge desires to find out just what is wrong, what persons are responsible for it and what conditions have brought it about, he will find from the literature now extant that opinions seem to be bitterly opposed, that apparently there is no concensus of opinion on the part of those who, to his mind, ought to know; and, also, that no harmonious act of legisla-

tion or regulation of the Navy Department has been presented which would solve the problem.

In his annual report for 1905 the Chief of the Bureau of Steam Engineering, Rear Admiral Rae, made certain recommendations concerning the engineering personnel, as follows:

"PERSONNEL.

"Again I consider it my imperative duty to invite the attention of the Department to the critical condition of engineering in the Navy.

"That this subject must receive serious and immediate attention, the deplorable accident on board the U. S. S. *Bennington* most forcibly emphasizes.

"Five and one-half years ago a momentous step was taken regarding the performance of duty in the Navy. A whole corps of specialists was virtually abolished, and the duties performed by these specialists were transferred to the line. The intent of the so-called 'Personnel bill,' the instrument by which the Congress authorized this change, was that all the younger officers of the Engineer Corps, the corps in question, were to perfect themselves in seamanship, gunnery and navigation, and were thereafter to perform both line and engineering duties indiscriminately, and at the same time the younger officers of the line were to perfect themselves in engineering and thereafter, likewise, perform indiscriminately the joint duties. The older officers of the Engineer Corps, although transferred to the line at the same time, were for obvious reasons to continue in the performance of engineering duty only. Thus eventually the line would be wholly composed of officers fitted to perform all duties connected with the movement of ships.

"The younger officers of the Engineer Corps were given two years in which to qualify for these new duties. How well they did it the records of the examining board and the fitness reports on officers bear striking testimony. As all midshipmen at the Academy had been given for years excellent prac-

tical instruction in engineering, no examination, other than that required for promotion, was demanded of them for qualifying for the performance of these joint duties. The intent was, however, that they should be ordered at once to the performance of this duty in subordinate capacities, as assistants of the older engineer officers.

"Owing to the absence of specific instructions to that effect in the personnel bill, combined with powerful adverse influences within the Department, for three years absolutely nothing was done by the younger line officers in acquiring engineering experience, and later, owing to the large number of ships kept in commission and the scarcity of officers, but little in that direction was accomplished.

"So long as the older officers of the former Engineer Corps remained available for service at sea, supplemented by a new body of warrant officers called warrant machinists, the engineering duty of the fleet was properly performed. Credit must not be withheld also from a few officers of the line who by their own personal exertions perfected themselves in engineering, and served, or are serving, with marked efficiency in most responsible engineering positions afloat.

"The older officers of the late Engineer Corps are rapidly disappearing from active service. In my last annual report I stated that there were 66 such officers at that time. The number has since been reduced to 43, and were it not that the services of certain retired officers are available, the Bureau would already be experiencing great difficulty in finding officers for the various responsible positions both on shore and at sea.

"So few officers of the line are taking up engineering seriously that the situation is becoming alarming.

"That the Department must do something to relieve this situation, and do that something at once, is only too obvious to the most casual observer of present conditions. Were the country suddenly plunged in war the Navy would find itself in no condition to win battles. As necessary as good marksmanship is the ability to carry our guns to the firing line

and to keep them there amidst the havoc created by modern ordnance, and this will never be done with amateurs in charge of the machinery. That line officers can become good engineers has already been proved, but they must have experience to become so, and that experience must be acquired in subordinate positions. No young officer out of the Academy but a short time, who would not be given charge of the deck except under the supervision of a senior officer, should be placed in charge of the engineer department of a ship, as has been done.

"Engineering logically belongs to the line, and the line should be made to perform that duty earnestly.

"In addition to the care and manipulation of the machinery of ships at sea, there are other duties which the engineer must perform and for which he must be fitted; these duties are the designing, inspection and superintendence of construction of that machinery. The Bureau holds, and it is not alone in the opinion, that the most successful designers of marine machinery are those who have had charge of it at sea.

"It therefore considers it most necessary that in the line of the Navy there should be a certain number of engineering specialists—officers who devote all their time and attention to engineering, for in this way only can the most competent designing engineers be obtained.

"As before stated, the situation is critical, and something must be done. The Bureau therefore submits the following plan for quickly supplying the Navy with a body of efficient engineers:

"All the younger officers of the line must be given engineering duty, and must be made to realize the importance of their responsibility. This duty must be at first in a subordinate capacity, and no officer should be given charge until his record shows his fitness for such duty. The examining board must be strict in its examinations for promotion, and before the board engineering must rank with seamanship, gunnery and navigation.

"That in the line there shall be a number of engineering

specialists, whose duty, both at sea and on shore, shall be engineering. These officers shall not perform duty at sea after reaching the rank of commander. A careful study of the necessities of the case has resulted in fixing the number of such officers at one in every ten above the rank of lieutenant, junior grade. These officers shall be recruited at the foot of the list of lieutenants—that is, when ten officers reach the rank of lieutenant below the last engineering specialist, the Department shall order an examination to be held of so many of those ten who volunteer for it for the purpose of selecting one officer to be assigned permanently to engineering duty. In case there are no volunteers, that, by a careful scrutiny of the record and fitness reports, one of the ten be selected for assignment to engineering duty.

"That officers so selected shall be given a course in higher marine engineering for at least one year at some school of engineering of reputation.

"That any officer of the line may immediately request permanent assignment to engineering duty.

"The final result of the foregoing plan would give a body of engineering specialists in the line of the Navy of about the following numbers and ranks:

Rear Admirals,		2
Captains,		7
Commanders,		11
Lieutenant Commanders,	29	62
Lieutenants,	33	
		82

"Of this number, 62—the lieutenant commanders and lieutenants—would be available for sea duty, say 30 at sea at any one time. This would give a sufficient number in each fleet to have a thoroughly competent engineer as chief engineer of each of the larger vessels, and a sufficient number to enable the commander-in-chief at all times to have available officers qualified to act in any case in which expert engineering

knowledge is necessary. These officers would have among their assistants the younger officers of the line acquiring experience, among whom would eventually be found those who would take up engineering permanently and become specialists themselves.

"The Bureau believes that such a plan, systematically carried out, would soon furnish the service with a body of competent engineers, and would place engineering where it properly belongs, in the line of the Navy.

"So much has been written in the public press advocating the establishment of a separate corps of engineers, similar to the one abolished by the personnel act, that it is deemed advisable to state the views of the Bureau upon that question.

"The Bureau is opposed to the formation of a separate corps of engineers in the Navy for the following reasons:

"1. Engineering, as the means of propulsion of ships, logically belongs to the line.

"2. Marine engineering of today demands for its votaries as high rank and as great consideration as that of the most favored branch of naval science; consequently a corps of such officers would require a certain number of positions of high rank in order to insure a proper flow of promotion, and there are not enough such positions of sufficient dignity for high rank to render the formation of such a corps justifiable.

"3. The engineer force of a modern, high-powered ship of war is a large proportion of the entire crew of such a vessel, and it is contrary to the ethics of military discipline that so many of the crew should be under the orders and direction of two separate and distinct bodies of officers.

"4. There is a widespread prejudice throughout the service against the formation of a separate corps of engineering specialists, which prejudice cannot be ignored.

"5. The controversies and jealousies incident to two bodies of officers performing duties of which the line of demarcation is very vague, so happily removed from the service by the amalgamation feature of the personnel bill, would be restored.

"6. The efficiency of a separate corps would be no greater,

if as great, as that by the proposed plan, based upon the principle that engineering belongs to the line."

Another plan, for providing officers for engineering work on shore, quite different from that recommended by Admiral Rae, was submitted to Congress by the Secretary of the Navy. The recommendations of the Secretary were embodied in a bill which provided for establishing a corps of marine engineers for shore duty only, to be recruited from graduates of technical schools. This new corps of officers was to perform the duties of designing, inspecting, constructing, overhauling and repairing naval machinery on shore, which work is now being done by line officers under the direction of the Bureau of Steam Engineering.

The above mentioned recommendations show that diversity of opinion on this subject exists even in the highest authoritative places in the Navy.

During the last two years a very voluminous discussion of engineering matters has been going on in the service papers, engineering magazines and the daily press. One very peculiar feature of this discussion is that a great many of the most critical attacks and arguments for various remedies are written by persons not in the Navy, and who, for this reason, are unfamiliar with the detail, the present status or the conditions of naval engineering. Many other arguments are also advanced by persons who are in the Navy but who have not been closely associated with engineering matters. The Navy now being so vast and complicated a concern, it is an error to suppose that an individual connected with it could be so conversant with all its details as to be an authority on all naval subjects. Therefore, the discussions whose arguments should carry the most weight are those written by men who, by reason of actual engineering experience or close association with naval engineering matters, are qualified to give an adequate and proper judgment. The following is a list of the most important discussions of this character written during the last few years:

Lieut. E. L. Beach, U. S. Naval Institute, September, 1902,

ex-engineer officer, who, since the passage of the personnel law, has served largely in line duties.

Prof. Ira Hollis, Address to Naval War College, reprinted in JOURNAL AMERICAN SOCIETY OF NAVAL ENGINEERS, August, 1903; former engineer officer, resigned from Navy, now professor of engineering at Harvard University.

Lieut. U. T. Holmes, JOURNAL OF THE SOCIETY OF NAVAL ENGINEERS, ex-engineer officer, who, since the passage of the personnel law, has served in both line and engineering duty.

Lieut. Comdr. R. Chandler, U. S. Naval Institute, December, 1905, line officer not ex-engineer, who, though not having performed engineering duty on a large vessel, has had considerable engineering experience on torpedo boats and destroyers.

Report of the Chief of Bureau of Steam Engineering, 1904 and 1905, official report of recommendations for engineering matters in the Navy. Rear Admiral Rae is a member of the first class of engineers that had a course at the Naval Academy.

By reason of actual experience the above writers may be supposed to be familiar with engineering needs.

The following is a copy of a comment written to the editor of the "Army and Navy Journal," probably by a warrant machinist in the Navy. This comment would show the general view of the warrant machinists, and this view also is based on actual experience.

"TO THE EDITOR OF THE ARMY AND NAVY JOURNAL:

"It is unnecessary to recapitulate the conditions in the Navy regarding trained engineer officers, for they are well known. But all the plans for producing "sea-going" engineers will give no tangible results for a couple of years at least, and meanwhile our costly fleet is deteriorating through improper care, and the department chiefs are hampered by lack of officers. Warrant machinists are attached to the larger vessels and do good work as assistants to the senior

engineering officer; but what of the smaller ships which have no warrant machinist or experienced engineer officer? These ships are frequently kept on the most wearing duty for a ship's machinery, station duty at out-of-the-way points, far from a base of supplies and repair facilities.

"The writer spent his first year in the service as an enlisted man, only six years ago, on a gunboat having engines and auxiliaries aggregating 1,400 H.P., which carried no engineer, only a line officer detailed to the duty; yet the vessel was kept on station duty in the southern Philippines for thirteen months without a visit to any port which had machine-shop facilities. Without disrespect to the able officers who, during that time, had charge of the engineer's department of the vessel, the estimate of time and money necessary to put the ship in condition when she finally returned to Cavite, proves conclusively the expensiveness of the present method, without quoting later and more widely known cases.

"There is no doubt that, in case of war, trained marine engineers would be commissioned, after satisfactory examination, to supply the need of the service for men to get the most out of the complicated system of motive power and auxiliaries upon which a modern warship depends for its usefulness as a weapon. This course was pursued in 1898; it was considered necessary then, when the service had an Engineer Corps, and it would undoubtedly be considered so now under similar circumstances—war, actual or imminent. The President has repeatedly said that a Navy, to be a good investment, from a purely financial standpoint, if from no other, must be efficient.

"The auxiliary machinery of a naval vessel is of a quantity and type that is not found on merchant vessels. It is the auxiliary machinery which needs the most care in ordinary cruising, and upon which many of the weapons of the vessel depend for their usefulness in time of action; so that, while an engineer commissioned from the merchant service, without previous naval experience, may do very well toward maintaining, in time of war, the motive power, and obtaining from

it a high degree of efficiency, he will be hampered by his lack of acquaintance with the complicated auxiliaries, and, if they have been previously neglected, the result will be a serious impairment of the efficiency of the fighting machine as a whole.

"This seems to lead conclusively to the necessity of having men who are experienced engineers in charge of the steam-engineering department of naval vessels in times of peace, to maintain the machinery in condition to answer the extreme demands of war time. It is pretty generally conceded in private life that a man, equally skilled in two or more kinds of work, does best, and is most efficient in that work which is most congenial, for which he has the most natural aptitude. Is it not, then, too much to expect that the Annapolis graduate, who, under the best existing or proposed regulations, takes up engineering duty for a time, will regard it as anything more than an incidental tour of duty, on a par with the duties of navigator, ordnance officer or even a watch and division officer? He will be an exceptionally conscientious young man if he tries to do more than keep his department clean and 'keep things going,' unless he naturally prefers the mechanical branch, in which case he will later be a good engineer spoiled to make an indifferent watch officer. The present and proposed regulations throw the intimate knowledge of the machinery on the warrant machinists, who are doing the work formerly done by the assistant, and in some cases passed assistant engineers, previous to 1899, with practically no prospect of promotion or adequate increase of pay, such as the junior officers of the former Engineer Corps had before them.

"True, at present a warrant machinist may take the examination for ensign, but in order to do so he (presumably an engineer by profession) must 'bone' navigation, ordnance, seamanship (including sail drill!), military law, etc., and if he is successful, under present regulations, he has no surety of being assigned to engineering duty only. Under existing conditions, the warrant machinists, who are frequently the

only officers connected with the Engineer's Department on the ship acquainted with the defects and needs of the machinery, have neither the authority nor the incentive to maintain the department in the condition in which it should be; nor should they be expected to take the place of the old Engineer Corps afloat, without better prospects than they have at present.

"Why not, then, extend contemplated legislation to allow the immediate commissioning of engineers to rank and duty under practically the same conditions as those under which the senior part of the old Engineer Corps was assimilated into the line? The candidates for examination to be drawn from civil life, from commissioned officers of the Service who prefer and are qualified for engineering duty, and from the warrant machinists.

"Let the examination be as thorough as may seem advisable to the Department, so long as the requirements are in reason, I make no doubt some of the warrant machinists will try for it. Of those who try, some may succeed, and then, however small the number of successful ones, the Department will have available just that number of officers who are competent for senior engineer's duty. If this number, with that of Annapolis graduates who prefer engineering duty, is not sufficient to fill the present need, open the examination to graduates of technical schools from civil life; but let the Department first be sure that a way to promotion is open to every officer in the service who is an engineer at heart.

"ENGINEER."

It is thus natural to conclude that the persons who would really be thoroughly familar with the deficiencies of the present conditions, the manner of properly providing for them, and who would also view these conditions from a military standpoint, are the commissioned officers in the Navy who are now, and have been, actually carrying on the engineering work of the Navy at sea and on shore. Officers who have done both line and engineering duties ashore and

afloat will be best qualified to judge the subject from all points of view.

The Bureau of Steam Engineering is the representative of the engineering personnel in the Navy Department, and it is the natural and logical thing to suppose that the chief of this bureau should be in the most favorable position to know the real needs of naval engineering.

If the question of the efficiency of naval engineering is to be dealt with, and a real remedy to defects applied by Congress in the shape of laws that will provide for wants now present and those coming in the near future, it is necessary to inquire into the actual conditions, and then to indicate the nature of any remedial legislation. The question then arises, Who is qualified to make pertinent recommendations concerning these matters?

It is not the retired or ex-engineer officer who has left the service years ago, and who very often does not realize the tremendous changes that have taken place, who is qualified.

It is not the line officer of high rank who has not had engineering experience or more than a superficial engineering education.

It is not the civilian who, though he may be most learned and perhaps a better engineer than any in the Navy, has never served on board a naval vessel, and knows nothing of naval life.

What is needed is a deep and intimate knowledge, based on actual experience, of the scope and character of the work, its present condition, and the effect upon it of any of the remedies that may be applied. The subject must be treated both from a military and an engineering point of view. Therefore the opinions of those who are doing the engineering work of the Navy are the ones that should be the most heeded.

The recommendations of the Chief of the Bureau of Steam Engineering, Rear Admiral Geo. W. Melville, for the years 1900, 1901, 1902, are as follows:

"PERSONNEL.

"Another year of experience under the provisions of the 'personnel bill' finds the status of steam-engineering interests in the Navy even less fully protected, and the number and condition of the force for their control even less satisfactory than when I made my last annual report.

"The magnitude of the work under this Bureau has rapidly increased with the additional ships in commission and the new ships building, while there has been a further decrease in the number of skilled officers available for supervising this work and but few signs of speedy replacement.

"I am fully aware of the futility and folly of decrying legislation simply because the desired results therefrom do not promptly materialize, but surely time enough has now elapsed since the enactment of the reorganization scheme to make criticism of its effects upon the Navy both proper and important.

"To any close observer it is convincingly evident that either the scheme was a mistake, or that the proper course has not been taken to carry out its intent.

"I am free to acknowledge that the events of the past year have brought only discouragement to those most deeply interested in a successful outcome of this new law, but I am equally candid in the belief that the cause of this discouragement lies not in the scheme itself, but in a lack of full appreciation, on the part of the Department, of the urgency of the need for haste, not only in providing the fullest opportunity for the acquirement of practical engineering knowledge on the part of the younger officers of the former line, but in enforcing their embracement of this opportunity in the most effective manner by Department orders. It will not do to depend upon unaided individual enthusiasm or details occasioned by the necessities of particular ships. Such a course merely temporizes with the present needs, fails in any rational degree to increase the force of naval engineers (even should it suffice to replace the annual loss), and is hopelessly ineffective to secure the most desirable results in the shape of a speedy

acquirement of general knowledge of engineering on the part of the new line as a whole.

"There is an immediate and constantly increasing demand for more expert engineer officers with which to protect the interests of the Government efficiently. This demand can only be met by assigning at once, both ashore and afloat—and in as great numbers as possible consistent with absolutely necessary other duties—the younger line officers as understudies and assistants to the experienced engineers now in charge of engineering work. In no other way can the wished-for result be quickly obtained. With a full opportunity provided I am confident there will be no lack of interest or energetic application on the part of the officers detailed.

"In a number of cases former line officers have had charge of the machinery of vessels during the past year, and while, in some instances, owing to lack of experience, their control has not been marked by all desirable efficiency, in no instance has there been evidenced any carelessness or lack of close attention to the work. On the contrary their devotion to the new duty has clearly been indicated.

"With steam engineering as a line duty this is pleasing to those who formerly had its entire control, and whose greatest fear might naturally be supposed to be that no efficient engineer officers would succeed them, and that the machinery department of ships would eventually be controlled by men of a more purely practical education (machinist) incapable of maintaining that constant stress toward increased efficiency found so needful to advance or of retaining the proud position of steam engineering of the United States Navy at the head of the marine world.

"In my last annual report I endeavored to express the unsatisfactory conditions clearly, but after the lapse of another year a review of these conditions, with additional experiences, is necessary.

"First, there are available over one hundred less engineer officers than just prior to the personnel act, and at which former time I had good cause to ask for an increase in the full number then on the list.

"With this great decrease in numbers came an increase in work, making it a necessity to curtail the usual and needed allowance of engineer officers for ships until the largest could have but one, and the colliers and smaller ships often none. To the latter were assigned, in most cases, former line officers as heads of the steam-engineering department, these depending principally upon the machinists for expert directions. That many casualties have not resulted is not, however, due to the propriety and efficiency of this arrangement, nor does it indicate a safe and commendable condition, for it has only been by dint of the most anxious and continuous care on the part of the depleted force that mishaps and breakdowns have been infrequent. In other words, a state of tension has existed and now exists under which it is neither wise nor safe to continue a day, as it is sapping the energy of good men. Instead of building up a personnel for the day of need, stronger than necessary for the time of peace, the engineer officers and men are kept at the point of elastic limit, and a new war today could not fail to develop a large list of physical incapables in the engineering branch the moment the additional burden was put upon them. True, we could call upon the civilian expert for help, and no doubt secure many good men; but how foolish to deliberately lean on this uncertainty when it is possible to school our own intelligent and devoted officers to a degree of satisfactory efficiency. That this schooling will eventually be accomplished I still believe; but my earnest request is for a greater effort to hasten it in order that no day of need will find us sadly wanting. I urge you to decided steps toward this object, pointing again to the fact that, at the present rate, new expert engineers are not being made in any rational proportion whatever to the displacement of the old ones from the active list, if indeed they are being made at all.

"You are fully cognizant of the intricacy and extent of the engineering department of a large ship. That of a smaller one bears the same importance and carries the same danger for the inexperienced. You can, therefore, judge how impos-

sible it is to create in a few months expert engineers from even the most intelligent officers unused theretofore to machinery. Experience daily under all conditions of service alone perfects efficiency, when combined with intelligence, and it is this experience I ask shall be given now to all line officers possible, below the grade of lieutenant commander, both at sea and ashore. From the many we are sure to gather a fair proportion particularly adapted to the work and with natural proclivities toward mechanics. These will be the real additions to the engineering branch, and will increase as greater numbers come from the Academy. The others, fairly well versed in time, will fill the gaps in emergency or war, and with a universal general interest there will be no need to call for volunteers to man our ships in this department.

"Regarding the engineering departments of ships at sea in times of peace as well as war, compare for a moment the condition of a battleship depending for the full and proper operations of her motive power upon the knowledge of a single officer, the chief engineer, with that of another ship of the same class whereon any one of the line officers could, in emergency, take efficient charge of the machinery, and several indeed assume and completely fill the position of an expert in that department. The ideal condition of the latter is what we are now striving for, since engineering knowledge has been recognized as of the most vital importance in the service, and it is to the realization of this I still hopefully look, despite the many visible obstacles.

"That I should betray unusual anxiety on this question can only be through my intimate knowledge of the conditions now existing and my earnest interest in the welfare of the service. My views, I can properly say, should have more weight upon this point than the views of any other naval officer or board, as these cannot view the situation from as comprehensive a standpoint as can the Engineer-in-Chief, upon whose shoulders for years has been the special care and protection of naval engineering.

"Inattention to my recommendations or apathy regarding

the immediateness of the necessity for more active and decided measures toward securing the desired conditions can surely result in nothing but rapidly decreasing efficiency, from which it will be continually more difficult to recover, and the cost of which will be significant in enormously larger repair bills, shorter-lived machinery, and a fleet of vessels in doubtful fitness for their designed service—a Cervera fleet, with limitless men, but lacking the technical experts needed to meet the extraordinary and ever-new conditions of emergency and war.

"I regret I have failed to impress you to the point of action by my former communications. Had a series of calamitous events occurred during the past year to make graphic the insufficiency of the present force of expert engineers, I am sure potent remedial measures would have been promptly taken by the Department. But while glad indeed to have disaster averted, I can assure you that danger now exists. It lurks in the silence of seeming security, but a knowledge of its presence should increase the desire to hasten its removal. Fortune alone has postponed casualty.

"The country can safely count on the valor and fidelity of its officers and men, but fidelity and valor without knowledge of the use of the arms given them with which to do battle can avail little against an efficiently drilled foe, and will afford scarcely more than an exhibition of heroic sacrifice, as needless as it would be cruel. The arms of a battleship are her machinery and her guns, 'useless each without the other,' and strong to victory when working well together. No deep thought is necessary to understand this, in the light of late experiences. The very highest degree of excellence in both the condition and handling of each is the price of successful encounter, or at least is the expectation of the country. A ship motionless or helpless to maneuver well could never make efficient battle, be her guns never so good or her crew never so brave. To guard against this the head of the steam-engineering department must be full of resource and armed by experience and engineering ability only attained by years

of intimate association with machinery under all conditions of service. Haphazard luck may bring a ship through without this, but sane judgment would condemn dependence on simple fortune, or a failure to use every possible effort to insure a most competent management in this most important of ships' departments.

"Engineering work is as full of interest as it is of importance, and the line may well be proud to preserve the control of it. The most intelligent are eager to become experts, and with their superior advantages need no primary instruction. They do need much experience with and observation of machinery at work and under repair or construction, and it is for the Department to decide upon the quickest way by which they can obtain this, and then to afford them the fullest opportunities for doing so.

"I have already suggested to have incorporated in the Regulations the best method for the needed training at sea, i. e., by departmental order to compel all line officers below the navigators of ships to alternate in duty in the engine room and on deck, and efficiency reports to be made quarterly to note their progress and class their ability.

"My plea is for the highest efficiency; for immediate recognition of its importance as well as of its present decadence through depletion of the number of technical experts without full provision for early replacement. I hold up the warning finger and sound the note of alarm."

"NAVAL ACADEMY.

"As it is to this institution that we look for the future supply of officers and for that discipline and weeding out of the unqualified as shall insure to the country a yearly addition to this arm of the service in every way fitted to the needs, it becomes necessary to exercise the most careful supervision of the curriculum, as well as to retain the best force of instructors.

"We cannot magnify too much the importance of care in

this first course of preparation of the naval officer at the Academy, and I must ask that continued stress be laid upon the value of fundamental thoroughness in the steam-engineering instruction there given. In order to secure the desired results, all the line cadets must have the fullest primary instruction, such as will furnish a sure foundation for satisfactory future advances. In this course the natural proclivity of the individual will become apparent, and special aptitude can be encouraged, while a proper interest in the science can be inculcated in all.

"With a view of increasing the value of the practical part of the sea training of these cadets, I would suggest to the Department the advisability of utilizing a more modern vessel for the practice cruise, at least of the upper classes, instead of the small vessels now so utilized.

"It would be beneficial, indeed, to the cadets, and at the same time a means of securing valuable data for the Department, if the cruiser *Cincinnati* or *Raleigh*, after the rehabilitation now in hand is completed, be used for the practice cruise. To my mind there are very great advantages to be gained by this means; the cadets would become accustomed to handle and operate a modern type of ship, such as they will find in actual service, both as regards rig and battery, as well as machinery. In the latter department the new water-tube boilers and improvements in the engines make these vessels particularly fitted for this instruction work, and only a skeleton regular crew need be added to the force of cadets available.

"It seems to me that some of the time still devoted by the Academy cadets to seamanship, in the original sense of the term, may be wisely sacrificed to steam engineering, and that anomalous vessels for practice cruises can be safely exchanged for a modern type of war ship. Smoke stacks have replaced topsails and top hamper, and the officer of the deck finds more need of skill in quick maneuver than in handling canvas aloft.

"WARRANT MACHINISTS.

"From all reports this class of expert mechanics have given general satisfaction, and an increase in their number is recommended.

"The establishment of this new grade at the very time the Engineer Corps of the Navy was absorbed by the line and nominally abolished, gave rise to some apprehension lest those entering the service as warrant machinists might do so in the belief that they would eventually comprise the real Engineer Corps of the Navy and be advanced to commissioned grade, thus beginning anew a naval feature so recently abandoned. For the purpose of preventing such unreasonable hopes and for promoting content, I advised in my last report that clear and precise regulations for this grade should be promulgated, defining their duties and properly limiting their aspirations to a full and faithful discharge thereof.

"As to a layman the difference between a naval machinist and a naval engineer appears to lie merely in the character of the work each has to perform, it may not be amiss here to recall the real difference in order to make clear the impossibility of the advancement referred to without an actual disregard for the present attainments of the naval engineer and entire blindness to the present and future necessities of the service.

"The naval engineer of today must be one not only specially qualified by aptitude for his profession, and secure in a thorough technical education, in which the theories governing his later work are firmly implanted in his mind, but he must also have had actual practical experience in the different mechanical branches of his calling, gained in such a favored way as to give him intimate knowledge of the prevailing methods of work without inflicting that long apprenticeship which binds the ordinary mechanic who must pay for his training by his actual output, and whose future employment must greatly depend on manual skill. Thus years are saved in the progress possible, and extensive knowledge of designs, with immediate practice in the embodiment of

these in actual work, is obtained. Thence comes the experience gained on shipboard with machinery under all conditions of service, and the observations of the machinery of foreign ships and the work at shipbuilding establishments ashore. These experiences are only obtainable, in their full extent, by the naval officer, to whom every courtesy is extended by his professional brethren at home and abroad. Both his position aboard ship and his comparative freedom from confining detail work enables the naval engineer to broaden his professional education by the comparison of the designs and operation of machinery of different classes of ships. It also permits him to keep posted in advanced shop practice and in current engineering literature, thereby enabling him to keep out of the 'hide-binding' grooves worn by a narrower class. So much is necessary to continually study and apply, as to make a leading position in this profession only possible to one with exceptional opportunities and surroundings. Hence it is not lack of native ability, but environment and training, which precludes the possibility of simply advancing the machinist class to that of the efficient naval engineer.

"Some one may say, perhaps, if they are so advanced, they will then have the opportunities alluded to. But the reply to this is that they will only have the opportunities in a small part, and will be unfitted to embrace even these in full measure. The years of education and training cannot be given to this class then, nor would it be sane to think of so doing when the special class is being already trained for it in a higher degree than could be possible to extend to men in later life.

"The naval engineer is closely acquainted with the trades of the machinist, coppersmith, blacksmith, pattern maker and foundryman, and can judge of the quality of work in all these branches, and can do fair manual work at each, comparatively slow, it is true, owing to not maintaining manual dexterity. He is essentially superior as a supervisor of general engineering work to the most expert hand in any single one of these trades.

"The warrant machinist may have fine intellectual attainments and excellent technical training, but of necessity he must be an experienced practical engine driver and machinist tradesman, and must possess a knowledge of his special work only obtained by years of actual practice in it. He is not required to have a broader education or one specially fitting him for the more strictly intellectual field of the naval engineer, nor can he hope to secure their attainments while his time is fully occupied with the actual attention to and care of machinery. It might just as rationally be supposed that a warrant boatswain could properly be advanced to the grade and rank of captain in the Navy. Both are actually possible through necessary legislation, but both are equally undesirable and unnecessary. Lacking any other source, we might turn to these expedients, but after years of experience we are no longer in doubt as to the superior results gained through the special education of our commissioned officers, whereby they are given advantages absolutely priceless and beyond the reach of any other young men in the land.

"Nothing herein is a just cause for discontent in the warrant machinist class, but rather a cause of rational content in showing reason for devoting to their proper duties time which might be otherwise spent in fancies wholly unreasonable.

"I will state here that I believe there must always be a real Engineer Corps in the Navy. This will not necessarily be actually so characterized, but there is no doubt but that the paramount importance of engineering work will draw apart to itself a class of the line having the greatest love for the science, and best fitted to carry on the work of this branch. It must certainly be the leading work and its field must be extended here, as it is ashore, to the inclusion of all the items in naval architecture that are properly special items of mechanical engineering."—*Report for the year 1900.*

"PERSONNEL.

"It is because it is much more difficult to solve questions relating to the personnel than of the materiel that the problem of securing a trained and efficient organization continues

to command the thoughtful attention and study of distinguished naval authorities. This interest in the development and maintenance of an efficient and satisfactory personnel is not confined to commissioned officers of the Navy, for from many outside sources I have received important communications concerning the necessity and manner of best securing an efficient engineering personnel for the future needs of the service.

"From both within and without the service suggestions have reached me urging the imperative need for strengthening the Navy along engineering lines. It is the requirements of the future rather than the demands of the present which should be provided for. In case of present necessity there are available for immediate need a large body of young officers who have been carefully trained in the guiding principles of engineering science. As these young men have also had considerable practical experience in professional engineering work, their services are in readiness for emergency. It will not be long, however, before they will lose interest, aptitude, confidence, and even efficiency in engineering duties if they should specialize in other directions. From this and other causes engineering efficiency in the Navy is rapidly decreasing. With such a state of affairs the outlook for securing a trained engineering force for future needs can hardly be regarded as satisfactory.

"It should not, therefore, excite surprise when I unqualifiedly assert that there has been retrogression rather than an advance along engineering lines during the past two years. This fact is so well recognized that numerous critics have even gone so far as to suggest that a separate engineer corps is again a necessity, and that the time is opportune for the enactment of such legislation. Such a suggestion can not be entertained at the present time, for I believe that it only requires a more liberal and different interpretation of the personnel law to secure many of the advantages that were contemplated by its originators.

"Ever since the passage of the personnel bill I have con-

tended that the measure of success to be secured from the law would be altogether dependent upon the manner in which it was interpreted. It was certainly the expectation of the Congress, and also of the personnel board, that the status of engineering in the Navy would be advanced by this law. In fact, the controlling influence which made possible the passage of the bill was expressed by the then Assistant Secretary Roosevelt in his report to you upon the subject, when he stated that 'Every officer on a modern war vessel has to be a fighting engineer.' This statement so succinctly stated the fact that it received the widest approval as soon as it was published. The reason for its ready acceptance was because thoughtful men had for a considerable time previous recognized the present as an age of engineering. Particularly in respect to naval matters had the public at large come to the conclusion that the modern battleship is a floating fort filled with complex machines, whose efficient care and maintenance can only be intrusted to a trained mechanical force, and the best efforts of this force can only be obtained when directed by trained officers. This applies to every department of the ship, and is only more applicable to the engineer department because that department comprises not only the most important but the greatest number of mechanical appliances.

"I am simply stating a fact when I assert that the number of trained and expert engineers in the Navy is being steadily reduced. The practical working of the amalgamation scheme thus far has been, in great part, to take the junior half of the old Engineer Corps and transfer them to line duties. Individual officers of the old line have conscientiously striven to perfect themselves in engineering duties, but up to the present time no systematic measures have been taken to train officers for the engineering needs of the future.

"The work is too important and the needs of the future too great to depend upon individual effort to secure sufficiently numerous and trained officers for such duties. Herein has been the radical weakness of the system that has been pursued since the passage of the bill.

"The failure to establish systematic methods for maintaining engineering efficiency was anticipated by earnest friends of the Navy during the discussions attendant on the passage of the personnel bill. When the subject was being investigated the question was raised of how officers trained in engineering duties were to be obtained under the amalgamation scheme. The positive assurance was given that this was provided for by alternation of duty between the deck and engine room. The point was then raised, Why should it not be specifically stated in the bill that this alternation must take place? The answer to such question was that this was a detail which could best be carried out by departmental order or regulation. The sincere advocates of the measure believed that it would not be best to limit the Department by specific operation of law. As the proposition was one which had been indorsed by the Secretary, and even commended by the President, it was presumed that the whole influence of the Navy Department would be exerted in improving the status of engineering. It was certainly expected by the Naval Committees of the House and Senate that the Department by regulation would provide for the engineering needs of the future; otherwise this need would have been carefully taken into consideration in the framing of the measure.

"It may be urged that the work of the Navy has greatly increased since the passage of the personnel bill, and that there has been an inadequate number of officers available for all kinds of duty. This is a fact; but for every three commissioned officers taken from the engine room and transferred to deck only one commissioned officer from deck has been sent below. This does not completely describe the extent of the depletion in the engine-room supervision. The officers sent from the engine rooms were transferred to the deck for permanent duty, while in most cases the junior officers transferred from the deck have only done engine-room duty for short periods. In explanation it has been stated that 100 warrant machinists have been appointed and detailed for engine-room duty. It must be remembered that all these warrant machin-

ists came from the enlisted force of the engine rooms and had very little experience in handling large bodies of men. Without detracting, therefore, from the merits and capabilities of the warrant machinists, they are not altogether fitted by previous training or experience to take charge of an important department of the ship. Their successors, in many instances, were petty officers whose experience at sea was very limited. The gain in the engine rooms from this source has been more apparent than real. If, however, warrant machinists are competent for such duty, it may be pertinent to inquire why the boatswains and gunners, who are also warrant officers, are not equally competent to carry on the routine deck duty. Such an arrangement would permit some of the junior officers of the line to receive engineering instruction, even if it were not deemed desirable that they should render service beneath the protective deck. In the British service boatswains and gunners carry on such deck duty on small ships, and it is to be presumed that our warrant officers would also be competent for the task if such assignments were made.

"As a result of this inadequate supervision in the engine rooms there has been a perceptible decrease in the efficiency of the machinery and a progressive increase in the cost of repairs. Definite data upon this question is difficult to secure, since this retrogression is progressive in character, and the full extent of the evil cannot be determined without searching investigation. The condition of the machinery of the torpedo-boat flotilla shows the trend of affairs.

"During the past year the disablement of torpedo boats has been of such frequent occurrence that the majority of the boats have been under repair a great part of the time. Many of these mishaps are serious in character, and the present condition of the flotilla affords an incontrovertible argument in favor of the proposition that practical engineering ability of high order is required for their successful care and operation. In my opinion the machinery of the torpedo-boat craft would not be in its present deplorable condition if engineer officers of experience had been detailed for supervisory duty in connection with the boats.

"It is strikingly significant that the decrease in machinery efficiency has been most marked in the case of the torpedo boats. With this type of craft it has been attempted to practically maintain the machinery in operation without the supervision of trained engineer officers. With such a system in operation it is not surprising that inefficiency should be the rule. Upon official trials the builders of such boats find it necessary to fill the engine rooms with supervising engineers of ability and experience, who command high salaries. After such boats are turned over to the Government it cannot be expected that an insufficient and unskilled force will be capable of operating them. The depreciation of the boats will take place at a rapid rate if either an inadequate or inefficient personnel is to be intrusted with their care and maintenance.

"That efficiency beneath the protective deck is no less important in naval warfare than efficiency above it cannot be doubted. The boiler plant is the heart of the vessel, and any weakness in that direction will be followed by general decline everywhere else. The difference between an efficient and inefficient force on board a war ship was shown at the battle of Santiago. The crowning act of that victory was the overtaking of the *Colon* by the *Oregon*. In this chase a battleship of 16 knots speed, manned by an efficient engine-room force, overtook a 20-knot armored cruiser whose motive power was inefficiently handled, since only about one-half the boiler power was developed on board the *Colon* that could have been secured by a skilled force of mechanics and firemen directed by a trained and educated complement of engineer officers.

"The Bureau has reason to eventually expect efficient service from the young line officers sent to engineering duty if such junior officers are made to understand that promotion only awaits those who qualify in this direction. The greatest good that must come from such details will be manifest in the future.

"It cannot be expected that immediate results will be se-

cured from this change in the future engineering training of the naval personnel. Satisfactory progress can only be secured by development. The experience of the cadet engineer system, whose abolishment cannot be too deeply regretted, showed that a perfected system of training engineer officers could only be secured by progressive experience and observation. Although the system was established at the Naval Academy in 1866, it was fifteen years from that time before a satisfactory course of instruction had been outlined that was in keeping with the needs of the service. It will require time, also, to perfect the present system.

"As the paramount purpose of these details must be to secure an engineering personnel for the future, I strongly advise that a large contingent of the junior officers be sent to the various navy yards and to other stations where engineering instructions and experience can be secured.

"These junior officers should be detailed for engineering work exclusively. If additional duty is assigned by other Bureaus, it cannot be expected that competent officers for engineering work can be adequately trained. This is not a question of specializing along engineering lines. It is rather a question of preventing inefficiency and demoralization existing in the future. Those undertaking this work must be impressed with the fact that there are unpleasant as well as attractive features in qualifying along every line of work. Any system of training which will permit the unattractive and difficult features to be avoided will make for future inefficiency.

"When the personnel law went into effect we had an engineering corps that was recognized as the equal, if not the superior, of that possessed by any other naval power. This efficiency was secured because the junior officers of the old Engineer Corps had been taught the lesson that to attain success much disagreeable work had to be done and many unpleasant duties performed. Those who are to succeed to the duties of the old engineer officers must be taught the same lesson of interesting themselves in the difficult as well as the

attractive work of the profession. The deep-seated prejudice that existed in the Navy against engineering duties has not altogether been eradicated, and from this cause it will be a difficult matter to create the interest and enthusiasm in this work that can be secured from more congenial and conspicuous assignments. It may not require much persuasion to induce many junior officers to acquire a superficial knowledge of engineering principles. It will need determined action, however, to compel a number sufficient for the engineering needs of the future to qualify to a degree that will make them proficiently capable of performing this important duty.

"The success achieved in the past cannot be repeated unless the same pride and interest in engineering work is taken by those detailed in the future to this duty. The necessity for looking ahead being recognized, the practical problem arises as to what details of policy are essential for such success.

"It has been said that the exposition of a military weakness can only be justified by suggesting remedial measures. In order to improve existing conditions, as well as to provide for engineering necessities of the future, the following recommendations are urged:

"1. That the policy lately inaugurated of detailing junior officers of the line exclusively to engineering duties be greatly extended.

"2. That a post-graduate course of instruction in marine engineering and design be established at the Naval Academy for those junior officers of the line who desire to familiarize themselves with marine engineering.

"3. That at least two war vessels be used in part for the general training of firemen.

"In the British Navy the training of stokers is systematically carried on in the cruisers *Northumberland*, *Nelson* and *Bellerophon*, vessels of 10,000, 7,600 and 7,500 tons, respectively. In these ships the stoker is taught that he has not only hands to use but a mind to employ. After a course of instruction the recruit has a better chance of becoming for

naval purposes not only a handy man but a reasoning creature.

"Such an eminent authority as Lord Brassey recommends that the modern armored cruisers *Powerful* and *Terrible*, ships of 14,000 tons displacement and 25,000 horsepower, be employed for the special training of the engine-room complements of British war ships.

"Fighting ships are even looked upon by the British Admiralty as desirable for the training of sailors. It has been officially announced by Lord Selborne that the squadron of training ships will not be resuscitated. Instead of developing the sailor lads on the royal yards it is proposed that they be sent to sea in fighting cruisers. This significant action by the British Admiralty shows the trend toward mechanical training for the entire ship's force.

"4. That several torpedo boats be kept in commission for the training and instruction of the machinists and water tenders of the torpedo-boat service.

"5. An urgent necessity has arisen for the training for naval duties of the youthful and inexperienced machinists enlisted in inland cities. These young men can be induced to seek a life career in the Navy if some substantial recognition is accorded faithful, efficient and continuous performance of duty. The number of chief machinists now in the Navy is simply inadequate for existing needs, and a sufficient complement can only be secured by giving the machinists, second class, a systematic and thorough course of instruction so as to make them familiar with the care, operation and repair of the various auxiliaries used in the naval service. These auxiliaries include capstan, blower and winch engines; evaporators and distillers; refrigerating, hydraulic and pneumatic machinery; also the simple forms of electric motors. These machinists should be instructed as to the manner of making all kinds of joints used for high-pressure purposes, the method of packing various forms of stuffing boxes, and, in general, the manifold duties that must be performed in the engine department of a modern war ship.

"It would be extremely advisable to send all machinists, second class, to a navy yard for practical work on ships under repair for several months. The experience and knowledge that they would gain from this experience would make them more efficient for duty on board ship, and the Navy would be the gainer from having such men trained, in great part, at a navy yard where the diversity of work on repairs would develop all who had an aptitude for a naval career. If such a course of instruction is provided, it can be confidently predicted that the corps of warrant machinists can be recruited from this source alone.

"As it is not probable that all the deserving machinists can from henceforth expect to secure warrant rank, I would urgently recommend that all machinists among the enlisted force who have served honorably for a period of twenty years be only assigned to duty at navy yards. There is much duty that these men could do at the naval stations, such as running tugs, taking charge of the steam fire engines, looking out for the various boiler plants, and taking charge of the machinery of the ships in ordinary.

"Under existing conditions machinists only remain long enough in the service to fit themselves for taking positions in the merchant marine. They are lost to the naval service just when they are most efficient, and such a deplorable state of affairs should be remedied, if possible. I believe that the Department has only to offer some substantial reward in the form of permanent duty at a navy yard to induce many machinists to render twenty years' faithful service, and to look upon the Navy as a life career, and not as a temporary vocation which affords an opportunity for travel and sight-seeing.

"6. That the warrant machinists be placed upon the same footing as regards pay and rank and emoluments as given other warrant officers. In some respects the warrant machinists are discriminated against, and so long as this distinction exists they will have a grievance which must interfere with the efficiency of the engine-room force. Every avenue to

promotion and increase of pay that is accorded other warrant officers should be given warrant machinists. The responsibility and character of the duty that rests upon this class of officers is as important as that devolving upon sailmakers, carpenters, boatswains and gunners, and the opportunity for advancement should be equally as great.

"7. That a special rate of pay be allowed those petty officers in the engine department who qualify as water tenders of torpedo boats. Such a substantial reward is given those who qualify in certain deck duties, and the same inducement should be held out to the leading petty officers doing duty beneath the protective deck.

"In connection with this subject of personnel there are features whose importance should be impressed upon the service at large. It is a certainty that the number of officers, doing engineering duty only, will diminish much more rapidly than is anticipated, and probably much sooner than is desired. By reason of the present interpretation of the personnel law the inducements for such officers to continue this work are very few. As attractive retirement features of the personnel law will soon be applicable to the majority of such engineer officers, it can be expected that the opportunities offered will be taken advantage of by many who are now doing engineering duty only.

"It would also be well for thoughtful naval officers to compare our work in training an engineering personnel for the future with efforts that are being made by other naval powers. Is the engineering course at Annapolis comparable with that given the British engineering cadets at Keyham? Are we in advance or behind other nations in systematically training the petty officers and stokers of the engine-room force?

"The war ships of the future must be provided with a strong complement of commissioned engineer officers. The number and character of the enlisted force working beneath the protective deck, as well as the extent and complexity of the motive power, demand and require that there be detailed,

for this supervision, a complement of educated officers possessing ability and high character. Either the junior officers of the line must be compelled to take up this work, or public sentiment will demand that the warrant officers be advanced to official positions commensurate with duties imposed upon them."—*Report for the year 1901.*

"PERSONNEL.

"It is now five years since the substantial features of the naval personnel bill were agreed upon by representative officers of the naval service and approved by the executive administrators of the Navy Department. Fortunately for the interests of the Navy, a period of fifteen months elapsed from the time the bill was introduced in the Congress until it became a law. During the intervening time the subject was studied by many thoughtful officers, as well as by the members of both Naval Committees. This reflection and investigation caused the merits and weaknesses of the measure to be pointed out and permitted the friends of the bill to arouse public sentiment in favor of the adoption of a proposition that had been carefully considered by officers of various grades and corps, and which was the practical outcome of twenty years' study of the subject.

"Three and one-half years have elapsed since the bill was made a law. After an experience of that length of time, it would seem as if a decision should have been reached as to the ultimate success of the project. It is simply stating a fact when it is asserted that one-half of the line officers on the active list of the Navy have yet to be convinced of the utility of amalgamating the duties of the deck and engineer officers. As for the retired officers, it is the exception to find those who have any sympathy with the scheme, or who do not predict an inefficient naval service as a result of the experiment.

"A careful perusal of the naval periodicals of America and Europe, as well as extended correspondence and personal interviews with hundreds of persons interested in the question, convinces me that the best friends of the Navy without the

service, as well as the Admiralty officials abroad, are still amazed at the experiment that we have undertaken. In fact, they are more doubtful than they ever were before of the ultimate success of the scheme. There is an old adage which states that the looker on sometimes sees more of the game than the players. This truth should be kept in mind in giving weight to the opinion of retired naval officers of our own service, of friends without the organization and of thoughtful foreign experts as to the beneficial operation of the law.

"It is but fair to state, however, that many officers in our own service, who should have the best means of observing the result of the experiment, are convinced that the passage of the law was in the line of naval development and advancement. But even some of these officers have admitted that more substantial results ought to be apparent by reason of the favorable conditions under which the law went into effect and in view of the period of time that the experiment has been in operation.

"While the amalgamation of the duties of the line and engineer corps was undoubtedly the essential feature of the personnel law, there were thoughtful officers who were more interested in the passage of the bill by reason of the fact that the measure contained provisions whereby voluntary and compulsory retirement was secured, thus insuring a healthy flow of promotion from the various grades. For over fifty years naval experts had been urging the enactment of legislation which would make it possible for officers to secure command and flag rank at a period of life when they were best able to take up exacting and important duties. Where seniority promotion alone prevailed, the mental and physical vigor of some officers had often become impaired by the time they reached flag and even command rank, and it was to remedy this weakness that it was deemed expedient to follow the experience of foreign powers by using radical measures to insure a regular flow of promotion.

"It should also be kept in mind that nearly every officer in the naval service either secured promotion or received increased pay as a result of the personnel law. The officers of

the Navy had been underpaid for many years, and any measure which tended to correct this injustice naturally commended itself to the favor of the service at large. This was no small factor in overcoming opposition that would otherwise have asserted itself, and the far-reaching effect of incorporating the amendments relating to pay and retirement cannot be overestimated.

"When the bill was presented to the Congress, its provisions were carefully studied by all interested in naval affairs. While fully cognizant of the necessity of enacting into law the retirement features of the measure, the members of the Naval Committees thoroughly realized that the question of amalgamation was the most important in the bill. This particular feature, therefore, received careful consideration, and only a campaign of education brought a majority of the committee to its support. It seemed apparent to both Naval Committees that the proposition conflicted with the tendency of the age toward specialization, and that the doom of engineering in the Navy was inevitable unless compulsory means were taken to compel officers to train in that direction.

"The measure was regarded by many as ill-advised because the bill did not explicitly make provision for compelling the performance of engineering duty. This objection appealed so strongly to certain members that the passage of the bill was imperiled by the insistence upon the part of some friends of engineering that special sections should be incorporated whereby this defect could be avoided. In answer to this contention it was shown that it would be extremely difficult to frame a law which would secure the desired result, since experience and observation upon the part of conscientious naval officers was absolutely essential before hard and fast rules could be made. It was the general opinion that the question of regulating the performance of engineering duty was one of administrative detail which the Bureau of Navigation could be depended upon to carry out, since the importance of engineering had been recognized by the Department in many official communications to the Congress. The Naval Com-

mittees were thus unofficially assured that departmental regulations and orders would be issued to overcome this anticipated weakness. It was also understood that when time and experience justified changes the Department would promulgate orders and regulations upon the subject.

"It was rather a revolution than progression in naval development which occurred when the Congress enacted a law whereby every naval officer of the line had in the future to become a fighting engineer. This epigram of President Roosevelt aroused earnest discussion, and caused the question of naval matériel to be subordinated to that of the personnel. It declared for a policy which amazed even the British Admiralty. The opinion of continental powers can possibly be gathered from the declaration of a naval attaché, who informed me that either the European navies had not an organization adapted to a modern warship, or else that the American service had committed itself to an error of policy which would require twenty years to correct. As there have been other American innovations which have amazed Europe and which have proved to be founded upon correct principles, the opinion of the continental powers as regards the personnel law may be equally erroneous. But where there is a radical difference in the training of the personnel, it is certain that there must be a great difference in the efficiency and strength of the several navies, and too much thought cannot be given to the question as to whether or not our present policy is the correct one. While it has not been difficult to convince naval experts that the principle of amalgamation is correct, but few converts have been found outside the United States to the belief that the principle can be practically applied except through progressive development. The naval authorities in Europe are thus more than skeptical as to the utility of the measure, since they assert that it conflicts with the customs and traditions of the Navy as well as with the tendency of the times.

"In measuring the results secured, it should be remembered that when the personnel law went into effect there were in the engine rooms of our war ships, in addition to an efficient

commissioned Engineer Corps, an exceedingly well-trained and intelligent complement of skilled machinists. These men had been drilled by engineer graduates of the Naval Academy, and a state of efficiency had been reached in our engine rooms that had not been surpassed by that of any other service. In the competitive examination that was held for the position of warrant machinist just after the close of the Spanish-American war the character and ability of the machinists of the Navy were put to an actual test. Almost without exception the successful competitors came from the naval ships. These men were not only well acquainted with the machinery of our war vessels, but they had been taught by example and precept the necessity of keeping every machine in a high state of efficiency. They had witnessed the courage and devotion to duty upon the part of the engineer commissioned officers, and thus had not only been made to implicitly obey, but they had been taught the necessity of efficiently directing affairs, so that when promotion was tendered such enlisted men they were competent to perform higher duties that could not be safely intrusted to those without naval experience.

"Two-thirds of these warrant officers have now been continuously at sea since the passage of the personnel bill. In many instances these men had over ten years' previous service and in some cases as much as twenty years' training in the Navy. As all had to serve a year on probation before securing warrant rank, and as a majority anticipated securing a shore assignment at the end of their cruise, these incentives have been no small factors in keeping warrant machinists up to their work and in maintaining efficiency beneath the protective decks of our war ships.

"The fact should be thus thoroughly appreciated that as regards the efficiency of the warrant machinist those now in the service are as a rule a picked body of men, who had not only received special training, but who had considerable experience in the several types of ships to which they have been assigned. Since the demand for skilled marine engineers is

very great in the maritime marine, it will be difficult to secure warrant machinists from that source, and, therefore, the Navy will have to train this class of men. As it cannot be expected that these men will be content with less recognition and privileges than is accorded other warrant officers, the number, of necessity, must be increased.

"These officers will demand, and it would seem as if they are justly entitled to receive, the same consideration as regards shore duty that is accorded boatswains, gunners, carpenters and sailmakers. The Department, therefore, can not expect to keep these men continuously at sea. A reasonable amount of shore duty will have to be given them or the Navy will lose the services of the elect. The personal inquiries that have been made at this Bureau as to the capabilities of the best of the warrant machinists show that the shipbuilding firms intend to draw upon the best of these men and that salaries will be offered which will induce the most efficient to leave the naval service in case these machinists are not to be put upon equality with the other warrant officers as regards shore assignments.

"While the warrant machinists have had shop training and experience at sea, it can not be expected that they possess the necessary scientific training to enable them to take up the most important duties that were performed in the past by the commissioned officers of the old Engineer Corps. These men may have the skill to adjust bearings, set a valve, replace a water tube in a modern marine boiler, overhaul a pump, and possess the requisite knowledge for operating machinery with which they are familiar, but in matters of organization the services of more highly trained men are needed. There are great laws of mechanics, physics, chemistry and thermodynamics which must be put to practical application by the chief engineer of a war ship. It is a thorough grasp of these principles, combined with practical sea experience and power of observation and study, which makes the competent marine engineer.

"It is not my desire to disparage the work of the warrant

machinists. These men are rendering useful and efficient service, and provision should be made whereby the elect might quickly secure commissions in the Navy. It is my great desire to encourage them and advance their material interests, but as a rule this class of officers can no more do the work of trained and educated engineers than can carpenters take up the duty of naval constructors, gunners assume the responsibilities devolving upon ordnance experts, or boatswains attain the skill and executive ability of skilled sea commanders.

"The belief that warrant machinists, if competent to take charge of the machinery of a modern war ship, will rest content with either the pay or position now accorded them is simply to invite another half century of internal strife in the Navy. It is nothing more than an attempt to revive conditions that existed when the screw propeller was first used. The machinists will simply tread the path that was broken by the officers of the old Engineer Corps, and success will be achieved by them in a short time, for the engineers taught them the lesson that great reforms can only be effected in a military service from pressure without rather than from efforts within the organization.

"It has been because the belief prevails in some quarters that the experience of a single cruise in the engine room will fit junior officers for the duty of a chief engineer, and that the practical duties at sea of the old engineer officers can be taken up by the warrant machinists, that there has been continued retrogression in the engineer efficiency of the Navy. To sustain the opinion that there has been retrogression the attention of the Department is invited to the consideration of Senate Doc. No. 175, Fifty-seventh Congress, first session, wherein the Paymaster General of the Navy, in a report in answer to a Senate resolution, forwards data as to the costs of repairs to the naval vessels.' This document is substantially a financial history of the ships of the new Navy, and shows the heavy expenditures incurred in keeping the vessels in a state of efficiency. This retrogression will not cease until at

least one-fifth of the 1,800 commissioned officers, midshipmen and warrant officers are assigned to engineering duty.

"Many young line officers have shown decided aptitude for engineering work, and have been assigned to such duty. The number, however, who have specially interested themselves in the work has been too small for the best interest of the service. There have been some who have taken up the work in an amateur fashion and as a diversion. The injury to engineering efficiency from countenancing this kind of duty is very great, since it demoralizes the enlisted force in the engine and firerooms, and tends to discredit the work in the estimation of those who should be made to interest themselves in the duty.

"The principle of amalgamating the duties of the line and engineer officers is, however, in accord with the trend of modern development, and it is by reason of this fact that the proposition received the hearty and unqualified support of the engineering interests throughout the country. It was an official recognition, upon the part of the Congress, of the dignity and importance of the engineering profession. It was also an emphatic declaration on the part of the legislative assembly that an organization which was suitable for vessels of oak was not compatible for the needs of ships of steel, and that the men beneath the protected deck in the engine rooms and stokeholes were as much an integral part of the ship as the men who served and trained the guns. This legislation, however, assailed the traditions of the service, and it was not surprising that opposition developed when it was presumed that vested rights had been encroached upon. This opposition was powerless in its appeal to Congress to reject the measure. It commanded greater strength within the naval service, and it is this influence which stands in the way of a liberal and generous enforcement of the unwritten but well-understood provisions of the personnel law.

"If the law is administered with a desire to make it a success, it will, beyond a doubt, give us the most efficient Navy in the world. It must, however, be administered in a way

that will prevent junior officers from showing a decided preference for deck duty, and this result can in great part be secured by refusing to promote those who have not had actual and continuous experience in the engine room, and whose semi-annual reports as to fitness do not show that they have been zealous and proficient in the performance of engineering duty.

"It is with pleasure that I bear testimony to the fact that during the past year a more determined effort has been made to carry out the intent of the personnel law to make every officer an efficient engineer. Junior officers of the line are now assigned by departmental order to special duty as chief engineers of vessels, and thus these young men are not only made to identify themselves more closely with the work, but it is possible to hold them to a more rigid responsibility for the character of the engineering duty performed.

"It is regrettable, however, that more junior officers are not detailed for duty in the engine and firerooms, since it is as essential to provide for the needs of the future as the demands of the present. The great scarcity of officers has probably made it difficult to arrange for alternation of duty on the scale contemplated when the personnel law was passed. There has been, however, no substantial abridgment in the number of officers assigned for deck duty, and it is an undoubted fact that fewer commissioned officers are now doing engineering duty than when the law went into effect. It will be said that there are 145 warrant machinists assisting these commanding officers, but practically all these warrant machinists were in the engine rooms of our war ships when the law was passed. At that time the warrant machinists were in the Navy, but without the promotion that has since been justly given them.

"There has been no hesitancy to intrust responsible duties in the engine rooms to warrant machinists, and surely many of the boatswains and gunners are capable of performing routine duty on deck, thus permitting a considerable number of junior officers of the line to be assigned as assistant inspectors

of machinery on shore. There can be no more risk in trying the experiment of utilizing the services of boatswains and gunners as watch keepers on the bridge than in placing machinists in charge of the engine-room watch. It would appear as if the deck experiment would be the less dangerous one, since in times of emergency either the captain, executive officer or navigator is within immediate call of the officer of the deck.

"By reason of the inadequate number of officers assigned to engineering duty on shore, the interests of the service have been greatly endangered. There is not a naval station nor shipyard where more officers are not needed for engineering duty. There is now in course of construction 250,000 horsepower of boilers of the Babcock & Wilcox design, and the only officer available for this duty is a veteran of the civil war. This officer is on the retired list, having sought voluntary retirement after forty years of active service. By reason of his special aptitude for the work the Bureau has continued him on duty. The task of inspecting marine boilers, of a design that the Bureau believes may be eventually selected as the approved type for the Navy, should not be intrusted to junior officers who might be unexpectedly ordered to sea at short notice. The Bureau would be pleased, however, to have several junior line officers ordered as assistants to the senior inspector of these boilers, but such important duty cannot be assigned to juniors who have not had extended engineering experience and training.

"About 125,000 horsepower of boilers of the Niclausse design are likewise in course of construction, and only one officer is available for this work. The good of the service would demand that several junior officers be detailed as assistants to each of the engineer inspectors of these boilers. The modern naval officer cannot efficiently operate machines unless he has had some experience in superintending their construction and installation. In the effort to keep the ships going at sea important duties on shore are being slighted, and surely more officers should be detailed for this special work.

"The personnel law contemplated that officers should reach command rank before they attained the age of 45 years, and that those doing engineering duty only, when attaining the rank of commander, should not perform service at sea. This provision was founded upon the opinion that any officer of scientific training and education electing to do engineering duty only, and with twenty-five years of naval experience, could render the best service to the Navy by supervisory work on shore, since physical vigor and age were important factors in the performance of engineering duty at sea. Those officers doing engineering duty only who are now beyond that age could be best employed in the inspection work on shore, since there is an urgent demand in the various naval stations and shipyards for officers possessing this special experience and training. But some junior officer should be in training to relieve every one of these seniors.

"It is pertinent to call attention to the fact that the competition between shipbuilders for naval work is more keen than it ever was before, and that there is not the margin of profit that was obtainable in the past by the contractors. Many of the shipbuilding plants now sublet considerable of their work, and this entails more rigid inspection upon the part of the Government official. The interests of the service are not being subserved by changing the inspectors frequently, for the naval experts are pitted against highly paid specialists who are not only loyal and zealous in representing the cause of their employers, but who have an advantage over the naval officers by reason of their long assignment in connection with the work in hand.

"By reason of the inadequate number of officers employed in the inspection of naval machinery, it is certain that the ships now in course of construction will not be the equal of those built in the past so far as relates to the motive power. This opinion is based upon careful study and experience, and is meant in no manner to reflect upon the integrity of the shipbuilders. The naval specifications are much more severe than those for mercantile work, and these requirements can

only be obtained by detailing as inspectors efficient and experienced officers whose education and training at sea gives them an intimate and professional knowledge of the needs of a war ship. The shipbuilders fully recognize the fact that an efficient and conscientious naval inspector, who holds them to a rigid and yet not vexatious responsibility, is in reality of great benefit to them, for such an officer when requested to tender advice is ever ready to give information. It has been repeatedly the case that the advice of such inspector has prevented the contractors from making mistakes which would have caused financial loss and long delay to the shipbuilding firms.

"The existing policy of overloading the naval inspectors is therefore not to the permanent benefit of the contractors. While it is true that an unscrupulous firm might secure a temporary advantage, the well established and reliable companies suffer pecuniary loss by vexatious delays. As the Department calls upon such inspectors for specific duties, it is impossible for them at times not to delay the contractors by the failure to inspect completed work. It is exceedingly probable that the courts will yet be called upon to determine the responsibility of the Department in this matter. Where there is an inadequate number of inspectors there is likely to be untrustworthiness in the character of the work, delay in construction, and heavy financial loss to the builders.

"The inadequate force assigned to engineering duty in naval matters has excited comment in the engineering world. One has but to read the editorial comments of the marine engineering periodicals to note how well informed the general public is in regard to engineering conditions in the Navy. The present age being distinctively an engineering one, there are thousands of educated and scientific engineers scattered over the country who take a deep interest in the design, construction, and operation of the warship. These men are closely watching the effect of the personnel law in the passage of which the engineering profession was no small factor. Whether or not it is its prerogative, the engineering profes-

sion feels that it is specially charged to see that the motive power of the Navy is kept efficient. The events of the past have shown that the profession is not powerless to accomplish its purpose in this respect, for it will always be accorded a careful hearing by the executive head of the Navy Department and by the Congress.

"While the personnel law is correct in principle, there is a general feeling among engineers that the purpose and spirit of the measure is not being carried out. Of the 1,425 commissioned officers and midshipmen, 78 in accordance with law are doing engineering duty only. Possibly 70 other junior officers of the line are giving all or half of their time to the performance of engineering work. Not over one-eighth of the officers below the rank of commander are thus doing engineering work. One would have to possess strong imaginative powers to believe that either the present or future engineering efficiency of the Navy is being looked out for under such circumstances. While there are 145 warrant machinists for duty in the engine room there are 286 other warrant officers for deck duty.

"In the vessels of the merchant marine there are as many engineers as deck officers, and surely a proportion of four deck officers to one engine-room officer should be ample, even in a modern navy. Excluding the marine officers, who have charge of the secondary batteries on some of the large ships, there are 1,856 warrant officers, midshipmen and commissioned officers. Allowing one-fifth of this total number for engineering duty ashore and afloat, there should be at least 370 assigned to this work instead of the 300 who are now doing the duty. The request of the Bureau that such a proportion should be assigned for engineering work cannot be regarded as excessive. It is certain that there are too few now doing such duty, and the continuance of the present policy will give us a fleet of war ships whose future engineering efficiency will more resemble the defeated than the victorious squadron at the battles of Santiago and Manila.

"In making an earnest plea for the complete administra-

tion of the personnel law, no element of personal consideration has influenced my action. I am a convert to, and not an original advocate of, the idea. I am most concerned that engineering efficiency in the Navy shall not be sacrificed, and that the great fighting machines, whose motive power has been designed at this Bureau, shall not fail in the work expected of them because they are not properly cared for.

"A navy without highly-trained and technically-educated engineers is a navy that will not stand the test of battle. It is an outworn system which attempts to have the medieval traditions of the sailing age prevail on board the fighting machines of the present generation.

"The result of forty years' experience in the Navy and the warning notes sounded by hundreds of persons within and without the service compels unequivocal declarations to be made as to the condition of affairs. Although these conditions are somewhat better than they were a year ago, we are passing through a period of engineering inefficiency which is not only subjecting the nation to great expense but is inviting disaster. The present condition of affairs cannot and should not be permitted to continue. The Navy Department and the Congress may be spurred to action from strong influences without the service unless a greater proportion of the commissioned personnel is assigned to engineering duties. As the engineering profession is carefully noting existing conditions, would it not be wise to do the work of strengthening the service along engineering lines within the naval organization rather than to have the Congress again take up the matter, when the formation of a separate corps of naval engineers, endowed with military rank and authority, will not only be a possibility but a decided probability?

"It may be asked why the time has not arrived when experiments should be tried of interpreting the personnel law more in the line of engineering progress and opinion. The fact should be emphasized that those who hold to this belief do not simply criticise existing methods. Such action would be inexcusable, for no loyal and patriotic man will expose the

military weakness of his country until he has shown wherein improvement is possible. Therefore, the friends of engineering, in the belief that the law is correct in principle but maintaining that it has been construed in a manner that is not conducive either to present or future engineering efficiency, request the Department to give careful consideration to the following recommendations:

"These recommendations relate to increasing the engineering influence, efficiency and duties of the commissioned personnel; of improving the condition and efficiency of the engineers enlisted force; and of intrusting to the distinctively Engineering Bureau of the Department the design, construction, installation and operation of all machinery other than that of ordnance.

"First. The establishment at the Naval Academy of an engineering experimental laboratory. The purpose and necessity for such an institution, and its relation to the question of an efficient naval personnel is well recognized in Germany, where engineering as a profession has been accorded even a higher status than it has in America and England. The German Admiralty has such a laboratory at Charlottenburg, and it is the belief on the Continent that the advance of Germany in naval and marine development is in no small part due to the magnificent work done at this station. The value of such an engineering laboratory to the Navy and to the nation, and its far-reaching influence upon technical education at Annapolis is of such great importance that it has been particularly referred to in this and preceding annual reports.

"Second. The establishment at the Naval Academy of a postgraduate course in engineering. If technical instruction of an advanced nature should be provided at Annapolis for junior officers who have special engineering talent, the advantages would be of a three-fold nature, since the junior officers, the Naval Academy and the service at large would be benefited by the work. The junior officers would be better fitted for undertaking the more important engineering duties of the future. The Naval Academy would be brought in

closer relation with the higher technical institutions of the country, and this would give the Annapolis institution an opportunity to compare educational methods, so that, where necessary, there could be improvement effected in the character of the instruction. The service at large would be the gainer by reason of the fact that every officer who took a course in postgraduate work would be a personal factor in preventing any decrease in engineering efficiency.

"Third. The detail of a junior officer of the line as an understudy and assistant to every officer on shore doing engineering duty only. Practically the only officers detailed as inspectors of machinery and engineering material are the few officers who have elected to do engineering duty. These officers by reason of their training and extended experience are particularly well qualified for the duty assigned them, but everyone of them is overworked, and the good of the service would be subserved by detailing someone to assist them. The junior officers assigned to this work would not only render a direct service to the Department in relieving their seniors of routine duties, but these understudies would be fitted for doing all the work in the future. One of the great menaces to naval efficiency is the fact that practically no junior officers of the line are doing engineering duty on shore. There can be no more important duty within the assignment of the Department than the training of an adequate complement of junior officers so that they will be fitted to perform the distinctively engineering work of the future.

"Fourth. That the junior officers of the line, by specific orders of the Department, in connection with the warrant machinists be placed in charge of the machinery of all torpedo boats and destroyers, auxiliary vessels and yachts, gunboats and small cruisers, as well as monitors and nondescript vessels. It is simply discrediting engineering to detail an officer of twenty years' experience to take charge of machinery of a small cruiser. In several instances officers of this experience have been withdrawn from important shore duties, where the Department had great interest at stake, to perform service at

sea which ought to be done under existing conditions by junior officers of the line.

"Fifth. A general order should be issued of such emphatic nature that the junior officers of the line would thoroughly appreciate the fact that promotion would be denied those officers who had not performed duty in the engine room, or who had not sought work of this character. Such an order would prevent a preference being shown deck duty, for however unattractive the work in the engine room might be, there would be no effort to avoid it if lack of such experience interfered with promotion.

"Sixth. That in view of the urgent demand for officers, and by reason of the fact that the Naval Academy is unable to send forth a sufficient number of graduates, that a law be enacted empowering the Secretary of the Navy to permit graduates of the technological colleges to compete for acting commissions in the service. That the successful competitors then be ordered to the Naval Academy for a one year's course of instruction in ordnance, gunnery and navigation, and that they then be sent to sea on board a modern warship for one year for practical instruction. That those who successfully complete the course prescribed by the Navy Department, both at the Naval Academy and at sea, be then given permanent commissions in the regular service. Such a policy would give us highly desirable officers for our immediate needs. They would not have that intimate knowledge of naval customs and traditions that had been acquired by the Naval Academy graduates, but they would have a much more rounded education, since the requirements for entering the technological colleges are much higher than those for entering the Naval Academy. From this source it is possible to secure some excellent men, and a reserve of trained officers for future contingencies could be educated in this manner. Such a system of increasing the personnel would bring the service nearer the hearts of the people, for in the course of a decade the alumni associations of every great university would have some of its representatives holding commissions in the line of the Navy.

"Seventh. That one hundred more warrant machinists be appointed. There is important work on shore for this class of officers to do, and the detail of warrant machinists who have been continuously at sea for years to temporary shore assignments would not only be an incentive to keep them in the service, but it would better fit them for carrying on their duty afloat.

"Eighth. That the system of instructing machinists second class, now in operation at the New York Navy Yard, be extended so that this training might be given at every leading naval station. The success of the school at the New York Navy Yard shows a necessity for extending the work. Once let the youg mechanics of the country learn of the opportunity to receive this professional and practical instruction, and an incentive to enlistment would be created that would make good the deficiency now existing in the number of machinists requisite for the ships of the Navy. The good results of establishing this school will not only be manifest in the decreased cost of repairs to warships, but in the higher efficiency of these men when reporting on seagoing vessels.

"Ninth. That in view of the fact that the water-tube boiler must soon of a necessity be the principal type in the naval service, that the status and pay of the water tenders be increased to a degree commensurate with the importance and nature of their duties. Considering the character of the duty performed by these petty officers, the water tenders are the most inadequately recognized and poorest paid of any of the enlisted force of the Navy.

"Tenth. That the title of the Bureau of Steam Engineering be changed to that of the Bureau of Engineering, and that there be placed under its cognizance all machinery which is distinctively engineering in character, other than that of ordnance. In view of the fact that the line officers of the future must have a knowledge of mechanical, electrical, pneumatic and hydraulic engineering, there should be a bureau at the Navy Department whose province it would be to design and have control of all of the machinery of this character. It

cannot make for naval efficiency to call upon an officer to be responsible for the repair, care and operation of a mechanical contrivance without permitting such officer to determine the character and design of the appliance. There is much in the word 'engineering,' and if the naval service will ally itself with the profession at large, a moral and substantial support will be tendered the organization that will be a tower of strength in times of emergency. The amalgamation of the duties of the line and engineer officers can only be accomplished by giving engineering a status that will command the respect and esteem of everybody within the organization, and this purpose can be greatly aided by enlarging the scope and influence of the only distinctively engineering bureau that now exists by operation of law."—*Report for the year 1902.*

In order to understand more fully the needs and conditions of this question, an examination into the actual scope of naval engineering work and its present condition should be made. The work assigned to the Engineering Bureau of the Navy Department is in general terms defined in Article IX of the U. S. Naval Regulations.

"U. S. NAVY REGULATIONS.—BUREAU OF STEAM ENGINEERING.

"*Article IX.*

"1. The duties of the Bureau of Steam Engineering shall comprise all that relates to designing, building, fitting out and repairing the steam machinery used for the propulsion of naval vessels; the steam pumps, steam heaters, distilling apparatus, refrigerating apparatus, all steam connections of ships and the steam machinery necessary for actuating the apparatus by which turrets are turned; also to requiring for or manufacturing all its equipage and supplies for ships prescribed by the authorized allowance lists.

"2. It shall design the various shops at navy yards and stations where its own work is executed, so far as their internal arrangements are concerned.

"3. It shall determine upon and require for or manufacture all its machinery and tools and shall erect and repair the same. It shall require for or manufacture the stores, stationery, blank books, forms, fuel, material and all means and appliances of every kind required for its own purposes.

"4. It shall superintend all work done under it.

"5. It shall have control of the organization and muster of the employees used entirely for its own purposes.

"6. It shall estimate for and defray from its own funds the cost necessary to carry out its duties as above defined.

"7. Orders relating to Navy Yard business connected with the Bureau shall be given by the Chief of Bureau to the commandants, who shall be responsible for their execution."

On board ship the senior engineer officer is charged with the care, condition and operation of the boilers; the main engines and their dependencies; the pumping, distilling, heating and refrigerating plant; the general workshop in which machinery repairs to all parts of the ship are made; the direction of all repairs to all steam machinery, and the care of all compartments within the limits of the machinery spaces. The engineer force on some of the largest vessels consists of nearly three hundred men, and is about one-third of the crew on the large armored cruisers.

A very curious anomaly of the regulations is that such purely engineering apparatus as the steering engine, capstan engine and the dynamo plant are not under the control of the engineer officer, though he is charged with their repair at sea. As may be supposed, this very strange condition leads to considerable waste of labor and no little trouble and annoyance on account of these machines being under the divided control of several officers and bureaus. The burden of any accident or trouble, in most cases, falls upon the engineer department, which has to repair and make good any breakdown, though it has no authoritative voice as to the proper handling or caring for of the machines. When a vessel is repaired at a navy yard the engineer officer does not control or direct the repairs to these machines, for they are under the control of

another yard department than his own. This very curious condition of divided control is brought about by the fact that the steering engine and the capstan engine are under the cognizance of the Bureau of Construction and Repair, and the dynamo plant under the cognizance of the Bureau of Equipment. Much simplification of the machinery itself, and of its operation, care and management, would be secured if all engineering matters were placed under the cognizance of the engineering bureau.

The regulations now in force defining the duties of the engineer officers are as follows (extracts from U. S. Navy regulations):

"CHAPTER XIII.

"ENGINEER OFFICERS.

"650. (1) The engineering duties of the ship shall be performed by officers of the line, below the grade of commander, detailed therefor; and, during such detail, they shall be known as the engineer officers of the ship.

"(2) Officers of the line assigned to duty with the engineer force of a ship, excepting those detailed by the Department, shall continue on such duty for six months from the date of such assignment, if practicable, and shall be relieved from it at the expiration of a year. Commanding officers of the vessels will inform the Bureau of Navigation of the dates of detail and relief of all officers performing engineering duty on board ship.

"SECTION 1.—THE SENIOR ENGINEER OFFICER.

"*Duty when Fitting Out.*

"651. (1) The senior engineer officer shall be detailed as such by the Department.

"(2) He shall, upon joining a ship fitting out, make a careful examination of all parts of the steam machinery used for motive power of the ship and her boats; of steering, hydraulic accumulator and turret-turning engines, when these are worked by steam; of the ash, anchor and other hoisting en-

gines, dynamo engines, pumps, fan blowers and ventilating engines, which are worked by steam; of the steam heaters, evaporators and distilling apparatus; of the refrigerating machinery and all other machinery of whatever description operated by steam, wherever found in the ship; of all steam connections; of the boilers and coal bunkers; of all tanks, cisterns and storerooms for engineers' supplies.

"(3) He shall satisfy himself that the spare gear belonging to his department is on board, tried in place where necessary, stowed in convenient location, and that every precaution is taken to preserve it in good condition.

"(4) Should he discover any defects or deficiencies, he shall immediately make a detailed written report of the facts to the captain.

"652. (1) He shall be responsible for the preservation and efficient working of all machinery under cognizance of the Bureau of Steam Engineering; the motive engines and their dependencies, both of the ship and her boats; the steam machinery necessary in actuating the apparatus by which turrets are turned; the steam and hydraulic turret-turning engines; the steam pumps, steam heaters, steam connections and pipes, distilling apparatus, refrigerating engines, forced-draft blowers and steam fire pumps.

"(2) He shall also be responsible for the cleanliness and good condition of all bulkheads, doors, valves, pipes and machinery within the engine rooms; of the boiler rooms, shaft alleys, coal bunkers, firemen's wash rooms, engineer storerooms and work shops; of all compartments and double bottoms within the line of such bulkheads, together with those compartments and double bottoms accessible only through the engineer compartments.

"(3) He shall also be responsible for the efficiency and good condition of all valves, cocks and pipes within the engineer compartments connected with hand pumps; and he shall see that the suction and bilge wells are kept free from ashes, dirt and grease.

"653. (1) He shall make frequent inspections of the steam

machinery under the cognizance of other bureaus, and report to the captain any repairs or adjustments which, in his judgment, are necessary to keep them in an efficient and good working condition. He shall have immediate charge of all such repairs, but shall not, for such purpose, disable the machinery even temporarily, except by order of the commanding officer. He shall submit separate quarterly reports of the condition of said machinery to be forwarded for the information of each bureau concerned.

"*Duty in Regard to Stores.*

"654. (1) He shall perform the same duties in connection with the inventory, examination, invoice, receipts, accounts, issue, expenditures, preservation, care, survey and preparation of requisitions, reports and returns of engineer's stores and supplies, as are assigned to the equipment officer in connection with equipment stores and supplies. He shall be allowed a yeoman.

"(2) After making the proper substitution of names, the regulations for the performance of these duties will be found in articles 564, 565, 566, 567, 570, 571, 572 and 573.

"*To Keep a Coal Account.*

"655. (1) He shall keep an account of the expenditure of coal for various purposes, and shall furnish the executive officer with such information as he may desire for making the required coal report.

"*The Engineer Division.*

"656. (1) He shall, at quarters, command the engineer division. He shall make the usual report in regard to absentees, and perform such of the duties laid down in articles 642, 644 and 645 as may be required.

"(2) The engineer division shall consist of all engineer officers of the ship, of all warrant machinists, and of all enlisted men of the engineer force, except such of the latter, not to exceed one-third, as may be stationed in the powder division.

"(3) It shall be mustered at quarters at such place or places as may be designated by the captain.

"*Station Bills.*

"657. (1) He shall make out watch, quarter, station, fire and cleaning bills. They shall, after approval by the captain, be hung up in a conspicuous place in the engine rooms.

"(2) These bills shall clearly show the duty and station of every officer and man of his force under all conditions of service.

"*Station.*

"658. (1) He shall personally supervise the operation of the machinery in getting under way or coming to anchor, and also, as far as practicable, at all times when unusual care is required to be given to the working of the engines.

"(2) He shall frequently visit the engine rooms during the day, and at any time during the day or night when his presence or services there may be necessary.

"(3) When in the engine rooms he shall be responsible for all duty performed there.

"(4) He shall, every evening, carefully inspect his department and see that everything is in a satisfactory condition for the night; that there is no probability of accident from fire, from the introduction of sea water, or from other causes; and that all the rules and routine orders of the ship relating to his department are being obeyed. He shall, at 8 P. M., make a report of the result of his inspection to the executive officer, if the latter is the senior; otherwise to the captain.

"(5) He shall not be required to keep a watch unless, in the opinion of the captain, it becomes necessary.

"*Duties of Subordinates.*

"659. (1) He shall assign to the junior engineer officers their routine duties in connection with the care, preservation and repair of machinery, apportioning among them the entire machinery of the vessel for which he is responsible, so that

each officer shall have direct charge of some particular part of the machinery. Such division of the duties of the junior engineer officers shall not, however, relieve the engineer officer actually on duty or watch of his responsibility for the proper performance of the detailed work of the day.

"(2) When midshipmen are assigned to the engineer force, he shall see that they acquire a practical knowledge of their duties, and, as soon as, in his opinion, they are competent to take charge of watch under steam, by day or by night, or with a day's duty, he shall so report to the captain.

"(3) He shall cause the engineer officers to instruct the petty officers and men in their duties, and to give particular attention to the training of the firemen in the management of fires, both with natural and forced draft.

"*Precautions Against Fire.*

"660. (1) He shall, in the disposition and stowage of stores, and in the use of lights, take every possible precaution against fire.

"(2) He shall see that the apparatus in his charge for extinguishing fire is always kept ready for use.

"(3) He shall require the temperature of the coal bunkers to be taken every watch when practicable and recorded in the steam log. Should there be any indication of spontaneous combustion, it shall at once be reported to the officer of deck.

"*Responsibility for Good Order.*

"661. (1) He shall be responsible at all times, whether under way or at anchor, for the good order and cleanliness of the engineer department, and shall see that it is at no time left without sufficient watch under the charge of a petty officer.

"(2) Each day before 10 A. M., he shall examine the engine and firerooms, coal bunkers, storerooms, and other parts of his department and see that they are ready for inspection, and that the work of the day is progressing in a satisfactory manner.

"*Coal Bunkers.*

"662. (1) He shall frequently examine the coal bunkers with the view of ascertaining the quantity of coal actually on hand, as compared with the amount called for by the coal account. Should he discover any material excess or deficiency he shall at once report it to the captain.

"(2) Before coaling, he shall ascertain the condition of the bunkers and of all watertight openings, and shall satisfy himself that no unauthorized materials are stowed in the bunkers.

"(3) After coaling he shall report to the captain what bunkers are filled, whether the coaling port or scuttles have been closed as to be watertight, and what watertight doors or hatches are closed.

"*Noon Report.*

"663. He shall report to the captain at noon each day the amount of coal consumed for the preceding 24 hours and the amount remaining on hand, and when under way under steam, the number of revolutions of each propeller for the past 24 hours and the average number per minute when in operation.

"*Report Injuries.*

"664. (1) He shall report to the captain whenever a boiler is injured; also any accident or derangement to the motive engines or their dependencies.

"(2) Should he consider it necessary at any time to reduce the load on the boiler safety valves, he shall so report to the captain. Any change made in the load shall be recorded in the steam log.

"(3) Suggestions.—Whenever he deems it necessary, it shall be his duty to make written suggestions or reports to the captain concerning the motive machinery and its dependencies, or other fittings of the ship for which he is responsible.

"(4) Should he receive an order the execution of which would, in his opinion, injure the machinery or boilers, or tend to extravagance in the consumption of fuel, he shall report his opinion and suggest a remedy.

"*Shall Not Disable Machinery.*

"665. He shall not at any time, for the purpose of repairs, disable the machinery even temporarily, except by permission of the commanding officer.

"*Lighting and Hauling Fires.*

"666. He shall not permit fires to be lighted or hauled, except in cases of emergency, without orders from the commanding officer.

"*When to Turn the Engines.*

"667. He shall not permit the main engines to be turned except in the obedience to a signal from, or by permission of, the officer of the deck.

"*To Report any Infractions of Discipline.*

"668. He shall be careful that all duty under his supervision is performed in a diligent, faithful, zealous and orderly manner. He shall report any officer or man who fails in this respect, or who, while under him, commits any breach of discipline.

"*Reporting Work Necessary on Arriving in Port.*

"669. (1) He shall, whenever the vessel arrives in port, report to the captain in writing all work needed for the proper care and preservation of the machinery and boilers, stating separately the work that can be postponed, if necessary, and that which cannot, without injury, be delayed. He shall note opposite each item whether the work can or cannot be done by the force on board, together with an estimate of the time required.

"(2) Should no repairs to the machinery or boilers be needed, he shall report that fact to the captain in writing.

"(3) The date and nature of the report shall in every case be entered upon the steam log.

"*Steam Log.*

"670. (1) He shall have charge of the preparation and care of the steam log, which shall be begun upon the day the ship is placed in commission.

"(2) He shall keep the steam log in accordance with the instructions and directions as printed therein.

"(3) He shall cause to be entered in the steam log a record of all injuries to any of the engineer force while within the engineer department.

"(4) He shall, as soon after noon each day as practicable, present the steam log, complete to date, to the captain for his inspection.

"(5) He shall furnish to the navigator daily the data required for the ship's log book.

"(6) Entries in the steam log pertaining to matters and events outside of the engine and firerooms, such as wind, weather, speed, state of the sea, sail carried, course steered, draught of water, etc., shall be copied from the ship's log book, when recorded there.

"(7) He shall prepare and, at the end of each quarter, submit to the captain for transmission to the Navy Department a smooth copy of the steam log, which must be signed and approved in the same manner as the original.

"*Remark Book.*

"671. He shall record, in a book kept for the purpose, the location of all spare parts of the machinery; a complete statement of everything that transpires in his department which may be of use to his successor in familiarizing himself with the machinery of the vessel and its history, and, as soon as ascertained, the most efficient rates of expansion in the different cylinders for various speeds, noting the page or pages of the steam log from which the data was obtained.

"*Transmitting Official Papers.*

"672. He shall forward all official reports, communications and returns through the captain.

"*To Inform Executive Officer Concerning Conduct of Men.*

"673. He shall keep the executive officer informed of the sobriety and obedience of the enlisted men of the engineer force and of their proficiency in their respective ratings.

"*Absence or Disability.*

"674. During the temporary absence or disability of the senior engineer officer, the engineer officer next in rank remaining on board shall perform the duties of the senior in addition to his own. Should, however, the absence or disability of the senior extend to a considerable period, the captain may, at his discretion, relieve the engineer officer next in rank of his duties as a junior.

"SECTION 2.—OTHER ENGINEER OFFICERS.

"*General Duty.*

"675. (1) The duty of other engineer officers shall be arranged by the captain in accordance with the number on board fit for duty and the requirements of the ship. Whenever fires are lighted under the main boilers for steaming purposes, they shall perform duty by watches; under other circumstances they may be permitted to perform day's duty.

"(2) When performing duty by watches the engineer officer on duty shall exercise a close supervision over the warrant or other machinists in charge of the engine-room watch and over all others engaged in running or attendance on the engines and other machinery, the boilers and their appurtenances. He shall be vigilant throughout his watch, and shall remain in the vicinity of his sphere of duty and be in readiness to respond promptly to any call. He shall be in the engine rooms at all times when it is probable that it will be necessary to work the engines to signals, and also when the watches are being changed.

"(3) When on day's duty he shall exercise a general super-

vision over the engineer's department and all of the force employed therein, and, when important work is being executed, shall be diligent in attendance and supervision.

"*Watch Duty.*

"676. (1) When performing duty by watches the engineer officers shall in no case perform their duty in more than five reliefs. Ordinarily the duration of a watch shall be four hours, but when the number of engineer officers, exclusive to the senior engineer is reduced to three, the watches may be of not more than eight hours, and when reduced to two, of not more than twelve hours duration.

"(2) When the number of engineer officers, including the senior engineer, is reduced to two, these two officers shall perform duty by watches whenever the main engines are running. When the engines are not running, they may, with the permission of the captain, do day's duty.

"*Day's Duty.*

"677. (1) When doing day's duty, the engineer officers shall in no case perform this duty in more than four reliefs, and the length of duty shall be not more than 24 hours.

"(2) When there are two or more engineer officers, exclusive of the senior engineer, the former shall take the day's duty in turn, subject to the limitation of paragraph 1 of this article.

"(3) When the number of engineer officers, including the senior engineer, is reduced to two, these two officers shall take the day's duty in turn.

"*Engineer Officer of the Watch.*

"678. (1) The engineer officer about to take charge of the watch duty shall not relieve his predecessor until he has satisfied himself that the condition of the machinery is as turned over to him, and he will require the officers and petty officers on watch to report to him the condition of the men and parts of the department under their control.

"(2) The engineer officer of the watch shall use every effort to maintain the motive machinery and its dependencies in an efficient condition, and to prevent any accident or injury of same.

"(3) He shall cause to be executed promptly any order received from the deck by signal or otherwise.

"(4) He shall report at once to the officer of the deck any derangement or probable derangement of the machinery which may affect the maneuvering powers of the ship. He shall not permit the speed of the ship to be altered without orders from the deck, except through necessity.

"(5) He shall notify the senior engineer officer as soon as he discovers anything going wrong with the machinery or boilers.

"(6) He shall cause to be faithfully executed and observed all instructions and directions received from the senior engineer officer in reference to the use, care and preservation of the motive machinery, and in other professional duties with which the senior engineer officer is charged by these regulations.

"(7) He shall at all times carry out any instructions he may receive from proper authority.

"(8) He shall preserve order among subordinates in the engine and firerooms and place upon the report book the name of any man who is guilty of any infraction of discipline.

"(9) He shall keep the steam log and make such entries as are required by the instructions contained therein.

"(10) He shall, so far as is in his power, prevent any waste of coal, oil or other stores.

"(11) He shall not absent himself from the place of his duties unless regularly relieved.

"(12) Reports to the officer of the deck and to the senior engineer officer shall, when possible, be made through voice tubes. When this cannot be done, the reports shall be carried by some intelligent subordinate; in the case of important reports, both means shall be employed.

"*Engineer Officer Having the Day's Duty.*

"679. (1) The engineer officer having the day's duty shall be responsible for all work being done in the engineer department and all engineering work being done by any one of the engineer force. In the morning he shall see that the morning orders are properly executed. In the evening he shall inspect the department between 7 and 8 P. M. and satisfy himself that all cocks and valves are closed or otherwise, as ordered; that all unnecessary lights are out, that all watertight doors and hatches that do not interfere with the work going on are properly closed, and that all precautions have been taken to guard against fire, leakage or other accident; and he shall report to the senior engineer officer, before 8 P. M., the condition of the department.

"(2) He shall carry out all provisions in article 678, paragraphs 1, 5, 6, 7, 8, 9, 10, 12.

"*Orders, How Passed.*

"680. All orders regarding the management of the machinery or the men belonging to the engineer force shall, except in an emergency, be given through the engineer officer on duty.

"*Permission to Leave Ship.*

"681. Engineer officers shall, before applying for leave to be absent from the ship, obtain from the senior engineer officer permission to do so. Should the senior engineer officer refuse such permission he shall report his reasons for so doing to the captain.

"SECTION 6—WARRANT MACHINISTS.

"*General Duties.*

"801. (1) Warrant machinists shall act as assistants to the engineer officers of the ship in all that relates to the care and management of machinery and boilers and their appurtenances, and shall perform such duty as may be assigned them.

"(2) Routine duties in connection with the surveillance,

care and efficient condition of the machinery, boilers and mechanical appliances, and the cleanliness of bulkheads and compartments in the engineer department will be assigned them by the senior engineer officer.

"*Watch Duty.*

"802. (1) They shall stand regular engine-room watch in not more than four watches. While on duty as engine-room watch officers they shall be under the supervision of and be subject to the orders of the engineer officer on duty, and shall be governed by the provisions of article 678.

"(2) The length of the watch shall not exceed four hours while the main engines are running, and shall not exceed six hours at any time.

"(3) They may, with the approval of the captain, be relieved from watch duty while the main engines are not running, whenever any necessary work of repair or examination or other exigency requires their continued presence and attention.

"(4) They may, with the approval of the captain, be excused from watch from 'pipe down' at night till 'all hands' in the morning, when the fires are not lighted under the main boilers for steaming purposes.

"*When Less than Four on Board.*

"803. When the number of warrant machinists on board available for duty is reduced below four, chief machinists mates or competent machinists mates of lower rating may be assigned to duty as engine-room watch officers."

At present there are very few vessels on which the senior engineer has assigned to him as assistants commissioned officers who have had sufficient experience and training to properly carry out the requirements of these articles. Nearly all the officers, other than the senior engineer, on duty in the engineer departments of our naval vessels, are assigned presumably for instruction, and, for the most part, have not sufficient knowledge or engineering experience to make them of much material assistance to the senior engineer. On him,

then, rests not only the burden of carrying on all the duties of administration and supervision, for which the regulations contemplate the services of several officers (apparently three or four), but also the duty of instructing the junior line officers in engineering knowledge. It is no more than natural that under the pressure of the multiplied duties many matters conducive to high efficiency and economical performance are not looked after as they should be, and for this reason marine-engineering practice in the Navy does not, at present, possess that high, all-around efficiency that would be possible if our vessels were provided with a proper force of skilled and experienced engineer officers specially educated for the purpose. A greater number than two or three experienced commissioned engineer officers is not needed on any vessel, but one is certainly not enough for a vessel of 30,000 I.H.P.

Many of the senior engineer officers on our large vessels at present are line officers who were graduated from the engineering course at Annapolis before the amalgamation of the line and engineers, and who have had experience for a number of years in doing engineering duty on modern naval vessels. There are also other officers serving as senior engineers who were graduated as line officers, but who have had considerable experience in engineering since the passage of the personnel law. Such officers, not ex-engineers, have not, however, had the benefit of a special course in engineering, there being no such course for line officers since the passage of the personnel law.

A course of this kind is being revived by having a certain number of junior officers assigned to take some special instruction in engineering under the direction of the Bureau of Steam Engineering. In the same general manner a course in ordnance is being conducted under the direction of the Bureau of Ordnance. These special courses were established by an order of the Navy Department in 1904, on the joint recommendation of Rear Admiral Taylor, Chief of Bureau of Navigation, Rear Admiral Rae, Chief of Bureau of Steam Engineering, and Rear Admiral Converse, Chief of Bureau of

Ordnance. A few of the officers who have taken this special course have lately been assigned to duty as senior engineer officers.

There is, however, no definite law or order of the Navy Department in force requiring that officers who have taken this course shall do engineering duty, nor are there yet any definite standards or requirements to which, in taking this course, officers must conform. There is yet no established policy nor regulation concerning the detail for engineering duty of officers who have taken this course.

The condition at present existing is that the engineer departments of our vessels of war are in charge of senior engineer officers, some of whom were formerly in the separate engineer corps and others who were of the old line and who have specially taken up engineering. There are relatively few of the old line officers who have become proficient and properly qualified to be assigned to independent duty as senior engineers or to engineering billets on shore; and no practical steps (having the promise of efficient results) are being taken by the Navy Department to determine who, if any, of such line officers have become proficient in engineering duties. There are also at present on duty in the engineering departments a considerable number of line officers—lieutenants, ensigns and midshipmen—who are there almost entirely for instruction in engineering, and who therefore can not be counted upon to do independent engineering duty.

The captain of each ship is required to send a report to the Bureau of Navigation of the amount of engineering duty performed by officers. A general remark as to proficiency in such duties is also made by the Captain for entry on an officers' record. There is, however, no general standard of requirement for proficiency in engineering. During the past six years a number of officers have gone through the rank of midshipman, ensign and junior lieutenant without doing any engineering duty. Officers who have had no previous engineering experience have in several cases been ordered to large vessels as senior engineers.

WARRANT MACHINISTS.

The passage of the personnel law created the warrant machinists who now perform the watch-standing engineering duty in the Navy, and who are also charged with the immediate conduct of repairs, overhaul and operation of machinery. They are practical operating engineers, starting out as good mechanics, who have secured their positions by years of experience as enlisted men in the engineer departments of our naval vessels. The present method of appointment secures in them a body of efficient, practical engineers and high-class mechanics. As a body they are thoroughly efficient and well fitted to perform the duties required by the Naval Regulations. They are, however, with a few exceptions, men who possess what may be called but an elementary education. As a class they are not acquainted with theoretical and scientific engineering nor with the principles of designing and building. They have not had the military training as officers nor the educational training in naval military duties. Many of them are efficient marine engineers and fully as capable of taking charge of an engineer department as some of the commissioned officers of little or no engineering experience. Most warrant machinists are able to pass for a license as chief engineer of a merchant vessel of unlimited tonnage, and a large number of them have these licenses. However, for lack of sufficient education, scientific knowledge or military training the warrant machinists *as a body* are not and, in the nature of the case, cannot be properly qualified to be put in charge of the engineer departments of our vessels of war.

It must be remembered that this statement is made of them as a class and that there are individual exceptions. It must also be remembered that the control of the engineer department of a large vessel of war calls for more than does the control of the engineer department of a merchant vessel, and that there are many military duties connected with it for which men selected as warrant machinists neither are nor can be expected to be qualified in all respects.

ENGINEERING CONDITIONS AFLOAT.

Next let us inquire into the actual condition of the engineer departments of our naval vessels. First let us take the large armored vessels. Their condition is reasonably efficient, their machinery is kept in reasonable repair, and full designed power or an approximation thereto can be obtained in service. The amount of money spent in navy-yard repairs and engineering supplies, is however, quite outside of the limits of reasonable economy. This is due to a lack of sufficient supervision caused by the shortage of qualified officers to do it, also to the rather inefficient method of administrating navy-yard work and purchasing and furnishing naval supplies.

Another matter in which our naval vessels as a whole are very deficient is the consumption of coal and supplies. The coal consumption of our naval vessels materially exceeds figures obtained in modern up-to-date marine practice. This lack of economy is due in a large measure to deficiencies in design and construction.

On the small vessels, which have less of the care and supervision of experienced engineer officers, repairs are in many cases excessive and far beyond what they should be The condition of machinery on some vessels is even poor and in some cases serious accidents and breakdowns have occurred due to an insufficiency of properly trained personnel both in officers and enlisted men.

The general condition of the machinery of many of our torpedo boats and destroyers is not good, and many are unable to obtain their designed speed. Extensive and costly repairs to these vessels are constantly being made. The condition is due to the lack of officers and experienced men assigned to the duty of caring for the machinery of these craft, and especially to the lack of engineering experience and knowledge possessed by those officers placed in charge of machinery, often a midshipman or an ensign who had had no previous engineering experience.

One thing that is fast leading to a very serious condition in the engineering departments is the lack of any uniform instruction in regard to the administration of the engineer department, conduct of work, training and stationing of men. The only instructions that have any official warrant or authority are found in those portions of the naval regulations that relate to engineering matters. These are necessarily very general, and have not been modified lately to suit new conditions. The steaming instructions are now the same as they were in 1895, although naval machinery has been revolutionized during this time, steam pressure doubled, water-tube boilers, turbines and superheated steam introduced. As far as the organization of the engineer division is concerned no uniform directions are given. Each senior engineer follows out his own inclination and opinions. The same matters are treated entirely different on vessels that are alike.

Owing to this state of affairs officers and men trained in the engineer department of one vessel have to learn to do things in a different way when they are sent to another ship. This condition can be remedied if a uniform standard for the administration and organization of the engineer department were devised and enforced.

There are now no proper authoritative instructions for methods of care, overhaul and operation that apply to the newer vessels. The instructions in the regulations, as has been mentioned before, have not been revised to keep up with the changes in machinery.

No books are available which describe in detail the proper methods of operation of the machinery of our latest vessels. Books for the instruction of midshipmen at the Naval Academy are to be found, but these, being designed for the instruction of midshipmen, are in many cases too general. The principal printed matter in the line of information concerning our naval machinery are the numbers of the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS.

It is, therefore, in a measure, difficult to gain a proper knowledge of the methods of care, operation and handling of

naval machinery except by actual experience, and by each individual intrusted with this duty finding out for himself by the process of trial and error.

There is no great difficulty in the way of securing standard methods of operation. All that is necessary would be to gather together the information from the different engineers in the service and publish the instructions under proper authority. The fact, however, remains that nothing of this character has been done, and the efficiency of naval engineering suffers accordingly.

The principal reason for this lack of attention in these matters is that there has been provided no force for doing the work. The Bureau of Steam Engineering is not provided with the necessary officers nor the civilian force to do it.

If there were at present an adequate proportion of sea-going line officers restricted to engineering duty as specialists some of these matters would receive more of their proper attention. Under present conditions each officer is required to be able to do so many different things that no one subject is gone into sufficiently to be thoroughly investigated; the tendency being for each one to get safely over with the work in hand by such means as are available and to leave the future to chance.

These comments are made with the idea of pointing out in what respects naval engineering matters are deficient and to show where the services of specially trained engineer officers are needed to make good these deficiencies. As compared with other navies, there are many things in which U. S. naval engineering excels, but the only way to maintain excellence is to remedy all weak points and defects that come to notice.

THE OUTLOOK FOR THE FUTURE AFLOAT.

With present outlook, in a few years all line officers who have had an engineering course at the Naval Academy will either be retired or will have reached ranks in advance of those from whom detail as engineer officers of vessels is made. The senior engineer officers will then have to be selected from

line officers whose previous experience, if any, will have been received under the present arrangement of a year, more or less, of engineering duty under instruction as assistant to the senior engineer. Moreover, such officers will not have had the benefit of any course in engineering except the rather short and superficial one provided for the midshipmen at the Naval Academy.

A question can very naturally be asked whether such officers as a class will be thoroughly competent to perform this duty and bring the machinery to the very highest state of efficiency. Will they be such as are best fitted to investigate the many technical engineering problems that will be coming up concerning methods and improvements in design and management? Will they be likely to understand the detailed essence of scientific naval engineering? The answer to the questions is perfectly obvious. It is folly to expect men of such little experience to be deeply versed in the technical details of a very involved subject just because they happen to have commissions as naval officers. The engineer departments of our complicated vessels will simply be put in charge of officers who are not familiar with them or with the methods of operating them, whose engineering experience will have consisted of a few months of instructional duty in the engineer department at some previous time. Several years may have intervened since such duty.

It is a serious fallacy to believe that the present course of three and one-half years at the Naval Academy, with its courses in mathematics, law, seamanship, navigation, ordnance, naval construction, military duties and the art of war all packed in with its course in steam engineering, can by itself fit an officer with the proper theoretical equipment to thoroughly understand the engineering knowledge that the control and management of a 30,000 I.H.P. engineer department requires. At present, time for study and research by officers outside of the duties that they are actually preforming is almost nil, everyone is more than busy with the details of his own work. If he is a watch and division officer the

requirements of his drills, battery and division occupy all his time, and he has no real time, opportunity or inclination to take up the study of engineering in addition.

The present course in engineering at Annapolis is not sufficient engineering education to thoroughly fit an officer for all the duties of an engineer officer afloat and ashore. To obtain additional knowledge a post-graduate course of some kind must be provided not only on question of design but also on care and operation for those officers who are to be assigned to duty in charge of the engineer departments of the important fighting vessels and the important engineering positions on shore.

EFFICIENCY OF WARRANT MACHINISTS.

In the system of appointment of warrant machinists as at present adopted and carried out, we have the promise of securing an efficient and thoroughly competent body of practical marine operating engineers for the purposes of taking engine-room watches and the immediate supervision of the mechanical work in the engineer department.

To obtain thorough engineering efficiency this body of practical men should be supervised and directed by highly trained, scientific and experienced officers who, having been trained in military and administrative duty, must also be thorough masters of the science of naval engineering both in theory and in practice. The average line officer under present conditions of training is not such an engineer, and can never be unless he neglects some of the other parts of his profession.

The warrant machinists, as a class, have not sufficient education and military training to fit them for independent authoritative administrative positions, such as that of the senior engineer of a high-powered naval vessel, the direction of the engineering department at a navy yard or the office of inspector of machinery at a large shipbuilding plant. There are among the warrant machinists a limited number who may become qualified in all respects for the performance of the

engineering duties of a naval officer both on shore and afloat. At present warrant machinists have the privilege of taking an examination for a commission under the same rules as gunners and boatswains, and two warrant machinists have been commissioned.

A warrant machinist, to secure a commission, must make himself proficient in a great many general and special naval duties which are entirely out of his environment, while performing his duties as a warrant machinist. Engineering is only one of the many subjects that must be mastered, but is the only one on which an officer performing the duties of a warrant machinist can properly inform himself. He has little or no chance to learn anything of military drill, navigation, modern seamanship, gunnery, handling vessels or the duties of the officer of the deck. Gunners and boatswains have a much better opportunity for becoming acquainted with the various duties other than engineering that a commissioned officer is required to know. The present arrangement places a severe handicap to securing a commission on the warrant machinist.

Another thing, if a warrant machinist secures a commission he may never be detailed for engineering duty, but may be ordered to other line duty with which he is necessarily more unfamiliar.

Warrant machinists who have mastered the engineering profession naturally desire to do engineering duty with which they are familiar; hence, a warrant machinist who is ambitious to advance himself is encountered with the project of having to learn a great many unfamiliar duties, being taken away from the duty he is familiar with, and then being required to do unfamiliar duty.

If it were arranged so that a warrant machinist could secure his commission on an examination in engineering subjects and could be restricted to engineering duty after receiving his commission, then there would be some equitable system for rewarding merit and extra professional ability in this corps.

If a special class of line officers for engineering duty is provided for, warrant machinists who have special abilities could be allowed to qualify themselves for the duties of these engineering specialists and be given commissions as line officers for engineering duty.

Such an arrangement would serve to heighten the tone of the whole corps of warrant machinists. It would provide for the bright, diligent, well informed and ambitious ones a real chance of promotion in line and in sympathy with their actual engineering duties.

This I believe to be what those warrant machinists who may be qualified for commissions really want. They desire the advantages of a commission, but also want engineering duty, recognizing that in that sphere they can serve the Government with more credit to themselves and to the Navy than if sent to unfamiliar duties distant from their training as engineers.

Any project for commissioning warrant machinists as a body is out of the question. There is no more real reason for this than there is to commission all boatswains and gunners. High educational attainments and thorough military training are absolutely essential to a commissioned officer. Warrant officers, as a body, do not have these attainments, and their duties do not require that they should have.

ENGINEERING MATTERS ON SHORE.

The engineering duty of the Navy on shore is a very large matter, and amounts to the expenditure of about five millions for repairs and eight millions for new construction each year.

The practical part of this work includes the conduct of the repairs and the maintenance in efficient condition of the motive power of all the vessels of the Navy, and the design and superintendence and construction of the machinery of vessels building. At present there are under construction thirteen first-class battleships, eight armored cruisers, three large scout cruisers, four submarines and a number of tugs.

As this work is one of considerable magnitude, it naturally follows that to secure efficiency in its administration a properly-trained and qualified force is necessary. There are now no provisions, in the present system of training, for training any officers to be put in charge of this work. The only indication of anything being done is the assignment of a limited number of junior officers to the Bureau of Steam Engineering for special engineering instruction. This special course has, however, as yet no promise of a definite existence, and is at any moment in danger of being discontinued.

The work of designing naval machinery, general supervision over repairs to naval machinery and the collection of engineering data is done at the Bureau of Steam Engineering. There is at the Bureau a civil force of 12 clerks, 16 draughtsmen, 2 messengers and 4 laborers. All civil employees are subject to the civil-service rules.

The draughtsmen are required to qualify in an examination for marine engine and boiler draughtsman, which examination is conducted by the Civil Service along lines recommended by the Navy Department. The pay of the draughtsmen is from $3.28 to $7.04 per day. The pay of the leading draughtsmen is small, considering the character of the work they are called upon to perform. A number of them are skilled and experienced designers of naval machinery. There is very little chance of promotion and no increase in pay for length of service, so that these conditions are naturally not very conducive toward developing or securing the highest class of expert designing engineering talent. It is owing to this that the Bureau is continually losing the services of excellent draughtsmen, more properly designers, who are attracted by higher pay elsewhere. There are few inducements now offered for an ambitious, talented marine-engineering draughtsman to enter the service of the Bureau of Steam Engineering where the limit of probable promotion ends with a pay of six dollars a day.

The work of designing naval machinery is now done by the draughtsmen under the supervision and direction of line

officers for engineering duty only, who were members of the former engineer corps and who have had the benefit of a course in designing machinery at the Naval Academy and many years of engineering experience at sea and on shore.

The number of such officers on duty at the Bureau has, however, been very inadequate for the proper carrying on of the work, and by reason of this dearth of officers many matters that to be thoroughly well handled should be taken in hand by officers with engineering experience afloat have been entrusted to civilian employees who, doing the best they can, have done remarkably well considering their lack of sea-going experience. The Bureau, moreover, has not been allowed to have a sufficient force of such civilian employees.

The work of naval engineering inspection is divided into two heads, Inspection of Machinery and Inspection of Material.

The work of inspection of machinery comprises the inspection of the construction and installation of the machinery of vessels building by contract. Inspectors of machinery are now (1906), located at the following places:

Newport News Shipbuilding and Drydock Co., building battleship *Minnesota*, armored cruisers *North Carolina* and *Montana*.

Wm. Cramps and Sons, building armored cruisers *Tennessee*, battleships *Mississippi*, *Idaho* and *South Carolina*.

New York Shipbuilding Co., building armored cruiser *Washington*, battleships *Kansas*, *New Hampshire* and *Michigan*.

Bath Iron Works, building battleship *Georgia*, scout cruiser *Chester*.

Neafie & Levy, building armored cruiser *St. Louis*.

Fore River Shipbuilding Co., building battleship *Vermont*, scout cruisers *Salem* and *Birmingham* four submarines.

Union Iron Works, building armored cruisers *California*, *South Dakota* and *Milwaukee*.

Moran Bros., building battleship *Nebraska*.

It is only occasionally that an inspector of machinery has

an officer as assistant. There are, therefore, practically no understudies gaining experience in this work, consequently, no properly trained reliefs are being obtained to take up this work when the officers now restricted to engineering duty are retired.

Each inspector has a limited force of clerks, draughtsmen and special mechanics appointed under civil-service rules. This force is in many cases inadequate to properly perform the duties of inspection. The pay allowed by the Navy Department for such civil force is in numerous cases hardly commensurate with the character of the service required. Special mechanics, supposedly qualified to inspect the installation of naval machinery and to conduct tests of same, are allowed the pay of $3.56 per diem. This is hardly enough to attract very high classed-mechanics.

To properly perform the duties of inspector of machinery requires years of engineering experience, both on shore and afloat, and a much more thorough knowledge of technical naval engineering than line officers are able to obtain from the present limited course in engineering at the Naval Academy.

Practically none of the younger line officers are now being assigned to gain the necessary experience as assistants that will enable them to properly perform the duties of inspector of machinery. Civilians having the necessary experience and training are not to be found, and in no case would they have the naval sea-going experience which is so very essential.

INSPECTION OF ENGINEERING MATERIAL.

This work is divided among nine offices, each office doing the inspection work for a certain district.

The following extract from the report of the Chief of Bureau of Steam Engineering will show the general scope of this work.

"INSPECTION OF ENGINEERING MATERIAL.

"The total number of pounds inspected and passed for the different bureaus of the Navy Department is as follows:

"For Bureau of—

Steam Engineering,	19,892,746
Yards and Docks,	24,568,109
Supplies and Accounts,	1,234,964
Construction and Repair	667,876
Equipment,	3,368,809
Ordnance,	381,343
Total,	50,113,847

"The total number of firms and manufacturing establishments doing work for the Government requiring inspection is 318, an increase of 32 per cent. over last year.

"Since these manufacturing establishments are scattered over a wide area of territory, the Bureau has established at convenient points headquarters for nine inspection districts.

"It has been the Bureau's endeavor to keep on duty at each headquarters a commissioned line officer of experience in the inspection of engineering material. Unfortunately, owing to the scarcity of officers available for such duty, it has not been practicable during the past year to carry out the above mentioned design. At present but six commissioned officers are available for the nine inspection districts. An officer who has more than one district to look after is greatly hampered in his work owing to the unavoidable time lost traveling from one district to another. The result is that the inspection work has suffered at times, and delay has ensued, because the naval inspector, who is supposed to decide promptly on questions of inspection as they arise, has not always been on the spot in the particular district where the question may have arisen.

"Then again, when so much of the naval inspector's time is consumed in traveling from one district to another it is impossible for him to exercise the close supervision of the work of any one district that is necessary to prevent friction between contractors and the assistant inspectors.

"The Bureau renews its recommendation made in last year's

report, namely: That young line officers be ordered to duty with the present naval inspectors of engineering material to be trained in the important duties of determining the fitness of the materials that make up the successful war ship.

"To assist the naval inspectors of engineering material the Bureau has a staff of civilian assistant inspectors, obtained by competitive examinations under civil-service rules. At the two important manufacturing centers of Pittsburg and South Bethlehem, Pa., the Bureau has well-equipped chemical laboratories with competent chemists. In these two laboratories are made all the chemical analyses required by the specifications governing the inspection of engineering materials.

"The character of the materials inspected is most varied. Among the most important are steel forgings for the heavy shafting and other moving parts of marine engines; gun forgings; anchors and anchor chains; steel boiler plates; castings of steel, iron and composition metal for marine engines; boiler tubes and condenser tubes; steel steam pipe and pipe of copper and brass; sheet copper and rolled sheets of composition material.

"The Bureau also inspects finished boilers, engines, and electric motors; power tools for machine shops; pumps for use on board ships; valves and engine fittings of all kinds; ice machines for naval use, and the forced-draft blowers used on board ship. The inspection of all auxiliary machinery used on board ship, within this Bureau's cognizance, is receiving careful attention, since it is realized that the efficiency of a vessel's machinery, as a whole, depends in large degree upon the trustworthiness of these small machines.

"Nearly all shipbuilding establishments buy these important auxiliaries from firms making a specialty of that particular work. In the past these finished auxiliaries for Government ships were sent to the shipyard, where only a superficial inspection of the finished product was possible. Now the Bureau insists upon a full and careful inspection of the materials entering into these auxiliary engines, as well as an inspection and test of the finished product before installation

on board ship. The good result of this method is very gratifying to the Bureau.

"This Bureau inspects all the structural material used in the construction of the storehouses and shops for navy yards and naval stations, also the structural material and machinery for coal-handling apparatus and coal-storage plants. The Bureau inspected all the material for the great floating drydocks recently built, and inspects the pumping plant for other new drydocks; material for steam and electric cranes for drydocks and for shops, as well as the finished cranes, are also inspected by the Bureau.

"The headquarters of the inspection districts are as follows:

"*Homestead Steel Works, Munhall, Pa.*—One officer, who also has charge at Shelby, with seven civilian assistants, one of whom has charge of the Bureau's chemical laboratory, do the inspection work of this district, which includes in addition to the great steel works of the Carnegie Steel Company, 53 manufacturing establishments doing Government work requiring inspection.

"*Midvale Steel Works, Nicetown, Philadelphia, Pa.*—One officer and three civilian assistants do the inspection work of this district, where 38 firms and manufacturiug establishments in Philadelphia and vicinity do Government work requiring inspection. At Midvale and at Bethlehem are made nearly all the large engine forgings of nickel-steel used in naval machinery.

"*Bethlehem Steel Company, South Bethlehem, Pa.*—One officer and two civilian assistant inspectors, one of whom has charge of the Bureau's chemical laboratory, do all the inspection work of the district, which includes five firms and manufacturing establishments doing Government work requiring inspection. The naval inspector of engineering material is also ordnance inspector.

"*American Steel-Casting Company, Chester, Pa.*—One officer, the same who has charge at Midvale, and one civilian assistant do the inspection work of this district. In this district are made a large proportion of the steel castings used in

the engines of our war ships. Many anchors for the Bureau of Equipment are also made in this district and inspected by this Bureau's inspector. There are in this district seven firms and manufacturing establishments doing Government work requiring inspection. The naval inspector in charge of this district is also inspector of machinery for the Navy at the works of Harlan & Hollingsworth, Wilmington, Del.

"*Harrisburg, Pa., room 21, post-office building.*—One officer, the same who has charge of the Midvale district, and two civilian assistants do the inspection work of this district. There are in this district twenty-one firms and manufacturing establishments doing Government work requiring inspection. Many heavy anchor chains are made in this district and inspected by this Bureau.

"*Brooklyn, N. Y., room 5, post-office building.*—In this important district two officers, one on the retired list, and three civilian assistants inspect the work done for the Government by fifty firms and manufacturing establishments. These places are located within a comparatively small area, so that inspection work is carried on without the great loss of time made necessary when the area to be covered by the inspectors is a large one. In this district are made many important auxiliary engines for naval vessels; the inspection of the material for these auxiliaries, as well as the inspection and test of the finished engines, must be as carefully attended to as the same work for the main engines themselves. The naval inspector of engineering material is also ordnance inspector.

"*District of Connecticut, with headquarters at Hartford, Conn., room 1, post-office building.*—One officer and two civilian assistants do the inspection work of this district. There are in this district thirty-five firms and manufacturing establishments doing work for the Government requiring inspection. In this district are made practically all the condenser tubes for Government vessels. The inspection of these condenser tubes is work of the greatest importance, for the Bureau recognizes that the relatively short life of these tubes

is a weak point in the endurance of naval machinery. The Bureau is endeavoring in every possible way to increase the lifetime of condenser tubes, and to this end the naval inspector of material in the district is directed to cooperate with the tube makers in their endeavors to turn out a tube that shall have more lasting qualities than the ones at present obtainable. In this district a large part of the copper and brass pipe used in the Navy is made, also rolled-composition material of various kinds.

"*District of the Middle West, headquarters at Shelby, Ohio.*—One officer, one warrant officer and one civilian assistant do the inspection work of this district. There are in the district sixty-three firms and manufacturing establishments doing Government work requiring inspection. At Shelby are made a large proportion of the smaller-sized steel boiler tubes for the Navy.

"*District of Massachusetts, with headquarters at Boston, room 102, post-office building.*—One officer and one civilian assistant do the inspection work of this district. There are in the district forty-six firms and manufacturing establishments doing Government work requiring inspection. These places are for the most part in Boston and vicinity. In this district are made many blower engines and steam pumps for the Navy, all requiring close inspection during manufacture."

As in the case of the inspectors of machinery, no young officers as assistants are provided, hence there are no understudies for these positions.

The inspection of engineering material is work of utmost importance to naval efficiency. The officer in charge of these offices, besides having had sea-going naval experience, must also have special expert knowledge of the manufacture and manner of testing engineering materials and machinery.

There are still a number of officers (ex-engineers) who are thoroughly qualified for this work, but in a few years their services will not be available, and now no one is being trained to take up this field of work.

NAVY YARD WORK.

The work of repairing and rebuilding naval machinery is done by the steam engineering department of the navy yards.

The engineering plant at such yards as those at New York or Boston is worth several millions of dollars, and to be efficiently conducted will require an experienced naval engineer to have charge and several officers well qualified in engineering to serve as assistants.

At the New York yard there are at times as many as thirty large vessels under repairs. It is needless to say that more than one or two officers are required to supervise this work at such times.

The engineering work of officers at navy yards includes the making of estimates for repairs, authorizing and deciding upon their necessity, preparing designs for alterations and repairs; and supervising and conducting the work when authorized. This is, of course, special work, and none other than a naval engineer of experience and training can thoroughly perform the duties required.

The line officer, as now trained, has neither sufficient engineering knowledge nor experience; the civilian engineer has no sea-going naval experience and only a limited knowledge of naval matters. A line officer who has specialized in engineering is the only one that can be depended upon to properly perform this work.

It is in the engineering work on shore that the greatest deficiencies exist. For the past five years there has been neither a sufficient number of officers nor a sufficient civilian force to efficiently perform all the naval engineering duties. The few officers who are qualified and who have had any extensive experience in the work are fast leaving the service by retirement and resignation, and none are being trained to take their places. There is no dearth of good material among the younger line officers for furnishing thoroughly competent inspectors, but none are being allotted for training for this purpose.

Unless the machinery of our naval vessels is kept up to the latest and improved state, both in design and construction, and also in methods of care and operation, our naval efficiency will suffer most seriously. It will not be kept in this state of efficiency unless a responsible body of officers who have had actual and extended experience, both in designing and operating, an engineering and military training and a scientific naval engineering and military education, is provided in the Navy.

The fact that ships must necessarily be built on shore and that materials for their machinery must be obtained there, seems to bring up the contention that civilian engineers who have no naval experience and who are not to go to sea can be placed in charge of the work of directing and supervising the building and repairing of naval machinery. Such engineers can be employed and, with present lack of officers, must necessarily be employed to a considerable extent as draughtsmen, computers and designers. But unless those supervising the design of naval machinery have had recent extended experience at sea in naval vessels they cannot know how to arrange this work so as to secure the highest state of operative efficiency. It must be remembered that the highest actual operative efficiency in service is the result desired, and unless the condition of actual operation is studied and observed by those who are to design and direct the construction of new machinery and equipment no very practical improvement is probable. It will be manifestly hopeless to expect that any body of engineers will be able to develop and produce machinery best suited for this purpose unless they have had, in some way, a chance to become personally, actually and intimately familiar with the operation of naval machinery at sea. The fact that large shipbuilding yards are continually taking engineers and naval constructors from the Navy to take charge and direct their work shows that the shipbuilder, who only has to build the ship, recognizes the need of actual naval experience to direct the building of naval vessels that they deliver to the Government.

Officers properly qualified to perform the duties of supervising and conducting the naval engineering work on shore can only be provided with certainty from one source, that is the line of the Navy. To obtain a proper knowledge of the technical details of this work such line officers must specialize in engineering.

If a certain number of line officers (say 100) with a reasonable number of years' experience, are selected to specialize in engineering and are assigned to duty as such engineering specialists, as was recommended in the report of the Chief of Bureau of Steam Engineering, and advocated in the articles written by Lieut. Comdr. Chandler, Prof. Hollis, Lieut. Comdr. Beach and Lieut. Holmes, and a sufficient clerical and technical civilian force as the needs demand, is provided, naval engineering matters will be placed on a proper basis and a degree of efficiency unparalleled in history and superior to that of any other navy, will in a short time be secured.

THE NAVAL PERSONNEL LAW: WHAT IT DID AND WHAT IT DID NOT DO.

The personnel law is based on the broad principle that the direction of all the fighting personnel and the handling of all material that goes to make up the fighting efficiency of the Navy must be under the control of the military officers of the Navy.

It holds that to educate and train an officer for the duties of military naval command he must receive an elementary or grounding knowledge in all the various matters that go to make the material and personnel of the Navy; and that among the important items of which knowledge is necessary, is engineering. Also that those in responsible control of the engineer department of the naval vessels, of engineering repairs at navy yards and of the work of designing naval machinery and of the supervision and inspection of the construction of the same, must have a sea-going naval and military training. It conforms to the idea that the general military naval training and the securing of the fundamental principles

of general naval knowledge can best be secured by training all officers who are to exercise command and authority over the fighting personnel in the same way, by means of the course at the Naval Academy. This is to establish at the beginning of their naval career certain uniform ideas of the essential general matters affecting the duties of an officer and the requirements of the Navy and of its personnel.

It is designed that unity of source and uniformity of early education and training will produce a community of general knowledge and ideals and a lasting community of sentiment and interest.

To secure these ends the personnel law provided that all officers of the line must go through the same course at the Naval Academy and that after graduation from that institution they are to be available for any duty in connection with the Navy not falling under the jurisdiction of the staff. This includes all command, navigation, ordnance, engineering and

NOTE.—Various statements are frequently made that the present course in the department of steam engineering at the Naval Academy is a better course than that given to the cadet engineers or cadets of the engineer's division. Such statements prove too much. It amounts to saying that a midshipman can as well and thoroughly learn several things as he can learn one by placing the same total time on it. Designing and experimental engineering is not taught at all. Thermodynamics is only vaguely touched upon, and building and construction is but superficially taught. There is not nearly sufficient time given to have anything but a general and elementary course in practical naval operating engineering.

The Naval Academy is well equipped for a good engineering course, but unless the students can spend sufficient time, is of little value.

The engineering course at the Naval Academy is sufficient to ground the young officer in a general conception of the engineer department of naval vessels and the ordinary methods of care and operation. This is all that is necessary for the training for the average officer for the general duties on board ship. But it is not sufficient for the more intricate and technical engineering work of designing, inspecting and building, nor sufficient to produce the highest excellence in the operation of marine machinery.

The midshipmen selected for the construction corps are given a three-years' technical post-graduate course. Naval engineering is as much, if not more, of an intricate subject than naval construction, and yet we are at present expecting to develop officers versed in this science who have not had a technical course in engineering and only interrupted and indefinite periods of engineering experience.

equipment duties afloat and all duty under cognizance of Bureaus of Navigation, Ordnance, Steam Engineering and Equipment on shore.

The following are some of the things that the personnel law failed to do, either by reason of inherent defects or by failure to carry out its intent.

It failed to designate with sufficient exactness how the duties between deck and engine room were to be divided. It named no specific, satisfactory standard requirement of engineering knowledge that all line officers must conform to. (It did, however, require the former engineer officers to qualify by an examination for the old line duties.)

It designated no means by which the old line officers were to acquire any additional engineering experience than they had previously.

(The midshipmen at the Naval Academy were provided with a better engineering course than had previously been given to the *line* cadets, but this course in no particular covers the scope of the course that was provided for the cadet engineers or for the cadets of the engineer division. This course is at present too elementary and too short and superficial to properly train men to become designing and constructing engineers and is even deficient as a training for operating engineers. As an engineering education it in no way approaches in scope and detail the engineering courses of high-classed technical colleges.—See Note.)

It provided in no way for securing officers specially expert in any of the special technical branches, though it goes without saying that to secure naval efficiency such special expert knowledge is absolutely necessary. Neither did the law create conditions tending to develop special study among officers or encourage any to specialize or excel in knowledge of any one subject. This produces a tendency for a wide general knowledge, but also general mediocricy in any special subject among officers, and also prevents the realization of excellence in any one particular thing.

It is the actual execution of the law, and not the law itself,

that must be examined in judging the conditions it has produced and the necessity of any alterations or change.

After the passage of the personnel law nearly all of the ex-engineer officers who were not restricted to engineering duty were transferred to deck duty, and most of them have been doing deck duty ever since. The line officers other than midshipmen detailed for engineering duty were very few, and those who were detailed were assigned for such short periods and under such unfavorable conditions for training as engineers that they did not acquire a very great amount of engineering knowledge.

The removal of the ex-engineers to line duties left very few officers for detail to the very important engineering duties on shore at navy yards, ship-building plants, offices of inspector of machinery, Bureau of Steam Engineering, &c. This resulted in the unavoidable set back of this part of naval-engineering work, the results of which can often be seen when a new ship is commissioned and in the enormous amount of money now being spent for alterations in vessels newly built. It is also a very regrettable fact that our naval machinery is not by any means as efficient or as well designed as it might be if matters were more thoroughly investigated and a proper force for carrying on the work had been provided. A large part of this engineering work on shore has been done and is being done by officers of little engineering experience and by civilians who are non-naval men. To secure thorough efficiency, sea-going engineer officers should perform a large part of the work now being done by these various inexperienced officers and civilians untrained to and lacking a thorough knowledge of its requirements.

(It is not meant to detract in any way from the faithful work that is being done by such civilians. They are doing about the best that the conditions will allow, and are in many cases underpaid for the character of the service rendered, but in the nature of the case they cannot perform special duties that require the training and sea-going experience of an officer.)

The general result of the passage of the personnel law is:

Line officers, as a body, have more engineering knowledge, which naturally increases their efficiency for command. This is as was intended, and in this the law is an unqualified success.

All the personnel and material on our vessels of war is being controlled by officers who have had the same general military training and who have naturally a military as well as an engineering ideal of efficiency. This is the principal advantage that the personnel law accomplished and it is of incalculable value. This is where amalgamation is a thorough success.

Our officers doing engineering duty, as a class, are much less expert and have a very considerable less experience in engineering than if the amalgamation had never taken place and a separate engineer corps had been maintained, or if engineering specialists were provided, as recommended by most naval officers who have written on this subject and as recommended by the Chief of Bureau of Steam Engineering.

The naval engineering work on shore has suffered severely. The work of designing machinery, inspection of material, construction of machinery, work of investigating engineering problems, securing data and information concerning the efficient operation of naval machinery and the work of conducting repairs to naval machinery is not being done nearly as well as if there had been a separate engineer corps or a special branch of specialists. This is caused by lack of trained engineer officers and to the fact that a large part of the work has of necessity been turned over to civilians untrained and inexperienced in naval matters.

The condition of the machinery of many vessels in the Navy is not as good as if a separate engineer corps had been provided.

The amount of money spent for engineering repairs and supplies is more than if an efficient separate corps of engineers had been maintained or engineering specialists provided.

These ill effects last mentioned can be readily remedied if the general recommendations made by the Engineer-in-Chief are carried out.

It will be seen that it is the engineering work of the Navy, and more especially the engineering work on shore, that has been the sufferer. This being the case, the natural thing to do is to provide means for supplying the needs of the engineering work without detracting from the great good that the personnel law has done in other lines. This simply means to provide a sufficient number of officers specially trained in engineering to take hold of the engineering matters that are now on the road to deterioration. The only practical way to do this is to take an allotted portion (about 10 per cent. of those above rank of ensign) of line officers who have the best engineering qualifications and use them to do the engineering work, and then provide some means for securing a regular supply of such officer-specialists for the future. A thoroughly feasible method is that recommended by the Engineer-in-Chief. He is naturally the one person to have an authoritative say in the matter. His recommendations should be carried out in principle, at least, even if some of the details are modified to some extent.

An article on this subject which has, perhaps, attracted more attention than any other, is the one written by Lieut. Comdr. Chandler, in the "U. S. Naval Institute." This article states the general condition of affairs quite plainly. It is, however, more sanguine of the thoroughness of the engineering course at the Naval Academy than I consider the facts warrant. It also, I fear, serves to give the impression that things are not as black as they have been painted, and that we are getting along very well in engineering matters. The present condition is not one to be satisfied with. Engineering matters are not as good as they should be, and our efficiency as a naval power in time of war is going to suffer severely from our deficiency in engineering.

There is a condition that must be met soon. It is that we have no adequate body of officers properly qualified to perform the higher duties of naval engineering at sea and more especially on shore. No means have been taken to remedy this state of affairs, and the conditions are getting worse. Al-

though it may be able to provide for all that is necessary under the provisions of the personnel law, the fact remains that it is not being done. The essential idea of amalgamation is correct and has suffered little attack from those in the Navy. But the lack of provision for securing specialists to do the special work is the point that has been so largely commented upon and criticised by those directly interested in naval engineering.

Specialists are also needed in ordnance, electricity, torpedoes, pilotage and astronomy. They are needed in all of the special branches for the same reasons that they are needed in Engineering. If they were provided for, a surprising increase in the efficiency of our naval material would result. It may, however, be remarked that these other specialties have not received as great a shock of disregard as Naval Engineering has received during the last half decade.

Naval-engineering work of designing and building must be controlled and conducted, supervised and directed by the same class of officers that the country will hold responsible for success or defeat in battle. This work must be under the control of those who have been to sea, who have operated and controlled and been responsible for these mighty masses of machinery when acted upon by the mighty forces of nature. The moment the control of building, designing and repairing of vessels and their machinery goes out of the hands of those who have gone extensively to sea in fighting ships, then there will be made costly mistakes and blunders in the design and state of repair of these fighting weapons. The fact that the design of our vessels is at present and has been to a considerable extent controlled by sea-going officers has enabled our vessels to be, in general, superior in many matters to those of other navies. At present the most serious mistakes are those in which the opinions of the sea-going officers, who are actually responsible for obtaining the results, have not been properly considered or are overruled.

The *Bennington* disaster is but an outcropping of the untenable conditions that prevail in certain quarters. This dis-

aster and various other accidents, and the necessity for costly repairs to the machinery of new vessels, are simply a few things that point out to us that engineering conditions are not all right at present. They are far from being all right. They are often quite unsatisfactory.

It is not now a question of whether the personnel law as a whole is a success or whether the amalgamation of the line and engineers was a benefit. But it is a question of getting for our Navy a sufficient number of thoroughly qualified officers to look after the engineering duty both afloat and ashore and in arranging conditions so that such a body of engineering officers can take hold and at once stop the backward movement that has set in.

The oft-repeated citing of the fact that at one time there were on vessels of war soldiers to fight and sailors to sail, and that at a later date these two bodies were merged into one that did both the fighting and the sailing, is no argument whatever for the necessity or the continuation of the present go-as-you-please hit-or-miss conditions that now exist among the official personnel of the Navy as far as training and detail for special technical duty is concerned. To cite this ancient history and to apply it in the abstract is fallacious argument. Modern conditions must be met in a modern way, and reasoning from examples of ancient history is in no way germane to the question. The general principle of amalgamation is desirable, necessary and indispensable to thorough naval efficiency. Its necessity is grounded on the same needs that a nation has for a common language.

Engineering belongs to the line and should be kept there. Those who advocate the establishing of a new, separate staff engineer corps are in error and are reasoning in the past. But it is also indispensable that specialists be provided for, and encouraged to develop their specialties to the highest degree of excellence not only in engineering but also in gunnery and ordnance, in torpedoes and electricity, in hydrography and astronomy, and any other specialty that may be required for naval needs.

The personnel law provided much that was desired, but it is not complete; it only goes part way, and then leaves things to chance or further development. Further development is now what is wanted. The personnel law has reached nearly the desired point in providing for the general features, education and training. The next thing is to make proper and adequate provision for the special features and training. What is wanted is an amalgamation of ideas, interests and aims, but to secure the ideal results from such an amalgamation specializing to the very highest degree is necessary.

U. S. BATTLESHIPS *MISSISSIPPI* AND *IDAHO.*

DESCRIPTION OF MACHINERY AND OFFICIAL TRIALS.

The *Mississippi* and her sister ship, the *Idaho*, are twin-screw armored battleships built by the William Cramp & Sons' Ship and Engine Building Company, of Philadelphia, Pa. The contracts for these two vessels were signed January 25, 1904, the price for each being $2,999,500. These prices do not include the armor and armor bolts (exclusive of protective deck), ordnance and ordnance outfit and certain articles supplied by the Government.

The main engines were required to develop ten thousand indicated horsepower, when making one hundred and twenty revolutions per minute, with a steam pressure of two hundred and fifty pounds at the high-pressure cylinder.

The guaranteed speed of the ships was seventeen knots per hour for four hours.

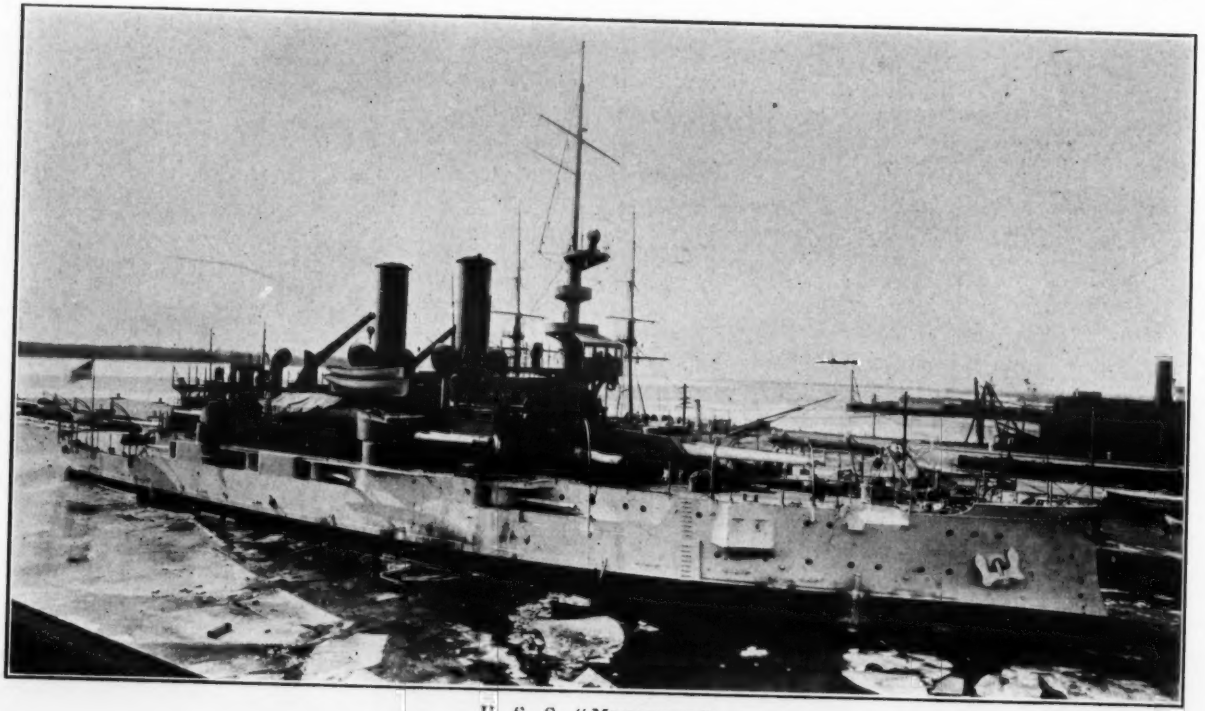
PRINCIPAL DIMENSIONS OF HULL.

Length on load water line, feet	375
between perpendiculars, feet	375
over all, feet	382
Breadth, extreme to outside of armor, feet	77
Trial displacement, tons, about	13,000
draught to bottom of keel, feet and inches	24-8

ELECTRIC PLANT.

There is installed and fitted complete an electric generating plant consisting of eight 100-kilowatt generating sets, all of 125 volts pressure at the terminals. These sets are located in two independent dynamo rooms.

Each set consists of an electric generator directly coupled to a steam engine, and both mounted on a common bedplate.



U. S. S. "MISSISSIPPI."

The generating sets and the engines and dynamos conform in all respects to the latest requirements of the specifications for the United States Navy.

ANCHOR WINDLASS.

There is a steam anchor windlass located in the windlass inclosure on the upper deck, which is provided with two wild-cats, the design being suitable for handling anchors of about 14,300 pounds, each with 2½-inch chain. The windlass is of the worm-gear type.

The windlass engine is designed for a working steam pressure of 150 pounds per square inch, but is able to withstand the full boiler pressure.

On the trial of the *Mississippi* both anchors were let go in twenty-eight fathoms of water, about fifty fathoms being veered on the port chain, and the starboard chain being veered to the bitter end. While heaving in both anchors, and while heaving in the starboard anchor after the port anchor was up, the windlass maintained a uniform speed. The wild-cats took the shackles and the swivel without slipping or surging. The engine worked in a very satisfactory manner, and there was no heating of the worm wheel or thrust block.

The tests of the anchor engine of the *Idaho*, on the official trials of that vessel, were equally satisfactory.

STEERING ENGINE.

The steering gear is located aft, and is of the standard type of the Bureau of Construction and Repair, consisting of a right and left-hand screw with traversing nuts directly connected, by side rods, to a crosshead on the rudder stock.

The steering engine is capable of putting the rudder from hard a port to hard a starboard, and *vice versa*, in twenty seconds, with a working steam pressure of 150 pounds per square inch.

The engine, however, is of sufficient strength to withstand operation under full boiler pressure.

PROPELLING MACHINERY.

There are two 3-cylinder, triple-expansion, outboard-turning engines of the vertical, inverted, direct-connected type, in two watertight compartments, separated by a fore-and-aft watertight bulkhead.

The order of the cylinders, beginning forward, are high pressure, intermediate pressure and low pressure.

The cranks are at angles of 120 degrees to each other, the intermediate following the high pressure, and the low pressure following the intermediate pressure.

The frames of the engines consist of forged-steel columns braced by forged-steel stays. The engine bedplates are of cast-iron supported on the keelson plates. All crank, line and propeller shafting is hollow. The shafts, piston rods, connecting rods and working parts generally are of forged, open-hearth steel.

The main valves are worked by the Stevenson link motion with double-bar links. There is one piston valve for the high-pressure cylinder and two each for the intermediate and the low-pressure cylinders.

REVERSING AND TURNING GEAR.

Each main engine has a reversing gear of the usual floating-lever, oil-controlled type.

In each engine room there is a double engine for turning the main engines, with steam at 100 pounds pressure. This engine drives, by worm gearing, a second worm which may be made at will to mesh with a worm wheel fitted on the crank shaft.

The turning engines have piston valves.

Provision is made for turning by hand.

ENGINE DATA.

Cylinders, number for each engine	3
H.P. diameter, inches	25½
I.P. diameter, inches	42
L.P. diameter, inches	69
Stroke of all pistons, inches	48
Valves, H.P., one for each cylinder, inches	14
I.P., two for each cylinder, inches	15½
L.P., two for each cylinder, inches	25½

Valve stems, H.P. diameter, inches	2¾
I.P. diameter, inches	2¾
L.P. diameter, inches	2¾
diameter through valves, inches	1⅝
Piston rods, diameter, inches	6
axial holes, I.P., inches	2
L.P., inches	2
Connecting rod, length from center to center, inches	96
crosshead end, diameter, inches	5½
crank end, diameter, inches	6½
Crank shaft, number of sections	3
diameter, inches	13½
axial hole, inches	7½
length, feet and inches	24–05
Coupling disks, inches	25½
thickness, inches	3
Crank pin, diameter, inches	14
axial hole, inches	7½
length, inches	15
Thrust shaft, diameter, inches	12¾
axial hole, inches	07½
length, feet	20
Collars, number on each shaft	11
diameter, inches	21½
thickness, inches	02
space between, inches	04
Line shaft, diameter, inches	12¾
axial hole, inches	07½
length, feet and inches	15–10
Stern-tube shaft, diameter, inches	13¾
axial hole, inches	07½
length, feet and inches	37–08½
Propeller shaft, diameter, inches	12¾
axial hole, inches	07½
length, feet and inches	29–05

PROPELLERS.

There are two 3-blade propellers, both outboard turning for ahead motion. The blades and the hub are of manganese-bronze.

The dimensions of the propellers are as follows:

Diameter, feet and inches	16–06
Pitch, as set, mean, feet	17
adjustable from 16 feet 3 inches to	18
Ratio of diameter to pitch	1.03

Area, projected, square feet	62.3
helicoidal, square feet	73.5
disk, square feet	214.0
Height of lower tip of blade above keel, inches	10¼
Immersion of upper tip of blade at low draught, inches	87¼

CONDENSERS.

Main Condensers.—There is one main condenser in each engine room. The shell is of steel, the water chests of composition and the tubes of composition. Each main condenser has a total cooling surface of 6,960 square feet.

Auxiliary Condensers.—There is one auxiliary condenser in each engine room having a total cooling surface of 380 square feet.

Dynamo Condensers.—There are two dynamo condensers, each having a cooling surface of 951 square feet.

FEED HEATERS.

There is a feed heater in each engine room having a heating surface of 601 square feet.

PUMPS.

The pumps are in accordance with the following table:

DATA OF PUMPS.

Auxiliary pumps.	Number.	Type, make and location.	Steam cylinders.				Water cylinders.			
			Number.	Diameter, inches.	Diameter piston rod, inches.	Stroke inches.	Number.	Diameter, inches.	Diameter piston rod, inches.	Stroke, inches.
Main air	2	Featherweight, Blake, engine room	2	9	1¼	18	2	18	1¼	18
Main circulating	2	Engine-driven, centrifugal, Cramp's, engine room	2	7a14	2	12	...	...	...	...
Main feed	2	Piston, vertical, simplex, Blake, engine room	1	16	2¾	18	1	10	2¾	18
Auxiliary feed	4	Piston, vertical, simplex, Blake, firerooms	1	12	2½	12	1	8	2½	12
Hot-well	2	Piston, vertical, simplex, Blake, engine room	1	6	1 7/16	12	1	6	1 7/16	12
Fire and bilge	2	Piston, vertical, simplex, Blake, engine rooms	1	12	2½	12	1	10	2½	12
Auxiliary condenser	2	Simplex, combined air and circulating, Blake, engine room	1	6	1½	10	1	10	1½	10
Dynamo condenser	2	Simplex, combined air and circulating, Blake, bunker space	1	10	1¾	12	1	14	1¾	12
Evaporating and distilling plant	1	Distiller circulating	1	12	2½	12	1	16	2½	12
		Evaporator feed, Blake type	1	4½	1⅛	6	1	5	1⅛	6

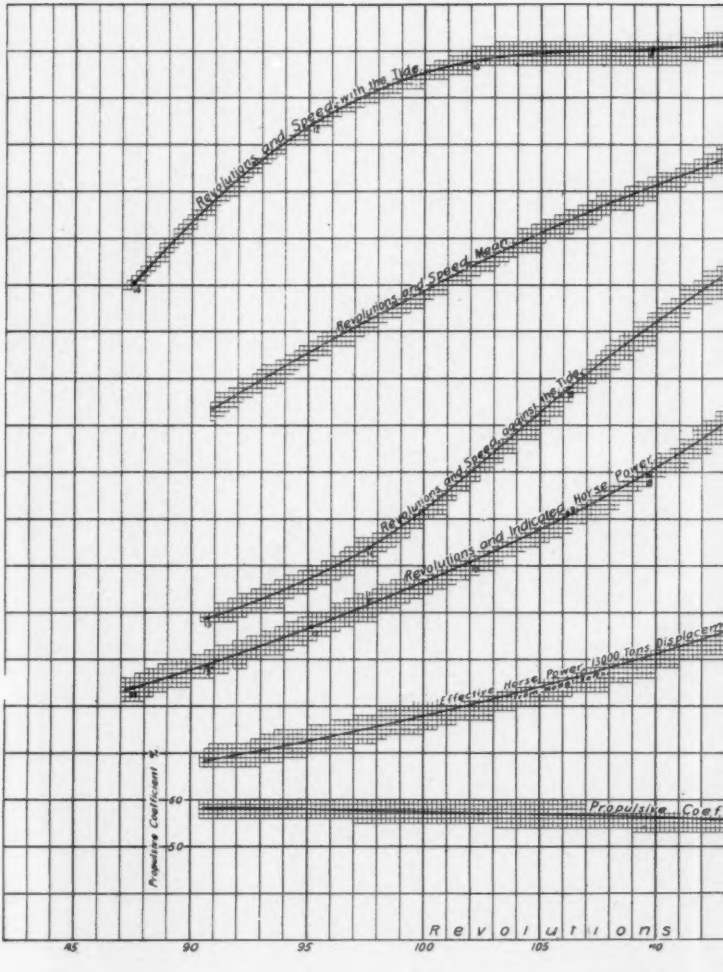
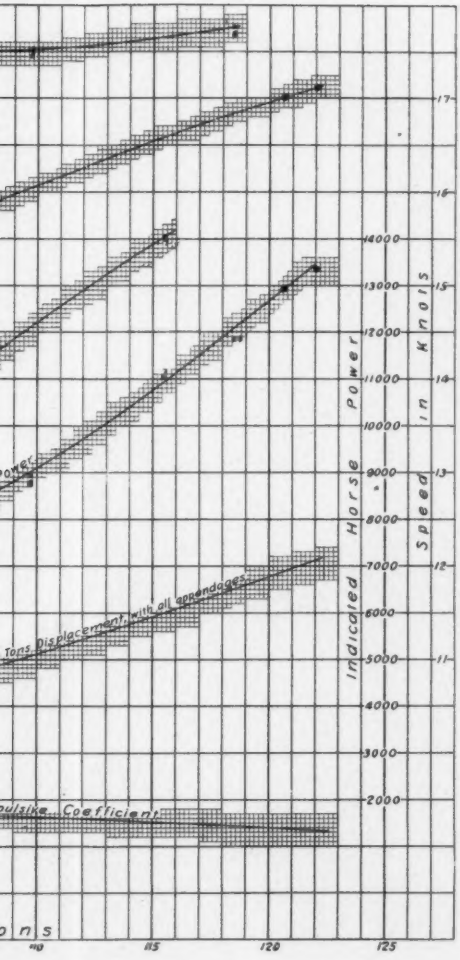

Revolutions and Speed with the Tide
Revolutions and Speed Mean
Revolutions and Speed against the Tide
Revolutions and Indicated Horse Power
Effective Horse Power 13000 Tons Displacem
Propulsive Coef
Propulsive Coefficient %
60
50
Revolutions
85
90
95
100
105
110

Plate I.



No of Run	Revolutions Mean	Speed	I M P Total
	Both Engines		
1	118 47	16 929	12177
2	119 76	17 170	12679
3	122 10	16 724	13398
4	121 56	17 593	13198
5	119 94	16 725	12614
6	118 47	17 756	11847
7	115 47	15 529	11023
8	109 73	17 527	8816
9	104 70	18 097	8119
10	107 00	17 397	7073
11	97 65	17 195	6763
12	95 15	16 727	5687
13	90 77	11 442	4835
14	87 58	15 048	4397

● Full Power Trial
122 03 17 11 13361

No of Run	Revs	Functions for averages of Revolutions	Speed	Functions for averages of Speed
1	118 47	1 = 118 47	16 929	1 = 16 929
2	119 76	2 = 239 52	17 170	2 = 34 340
3	122 10	1 = 122 10	16 724	1 = 16 724
4	121 56	2 = 243 12	17 593	2 = 35 186
5	119 94	1 = 119 94	16 725	1 = 16 725

4/480 09 4/485 16 4/67 993 4/68 135
720 92 121 29 16 998 17 034
1st Group 2nd Group 1st Group 2nd Group
120 02 16 998
● 121 29 ● 17 034
2)241 31 2)34 032
Average 1st & 2nd Groups 120 65 Average 1st & 2nd Groups 17 016

No of Run	I M P	Functions for averages of Indicated Horse Power.
1	12177	1 = 12177
2	12679	2 = 25358
3	13398	1 = 13398
4	13198	2 = 26396
5	12614	1 = 12614

4/50933 4/52406
12733 13102
1st Group 2nd Group
12733
● 13102
2/25835
Average 1st & 2nd Groups 12917

Dimensions of Propellers.

Diameter	15ft 6"
Pitch	17ft 0"
Helicoidal area	73.3 sq ft
Projected area	67.3 sq ft
Net area. Disc area	.344

U. S. S. MISSISSIPPI.

STANDARDIZATION RUNS.

DELAWARE BREAKWATER, OCTOBER 16 1907.

BUREAU OF STEAM ENGINEERING, NAVY DEPARTMENT, WASHINGTON, D.C. DEC 2 1907.

ate I.

BOILERS.

There are eight Babcock & Wilcox boilers of the latest improved type arranged in four watertight compartments. These boilers are of the following dimensions:

Length, feet and inches	9-01¼
Width, external, feet and inches	16-05¼
Number of furnaces	2
Number of headers	24
Grate surface, one boiler, square feet	96
Heating surface, one boiler, square feet	4,081
Grates, length, feet and inches	7-00
width, feet and inches	6-10¼
Pressure, design, working, pounds	265
test, pounds	400
Ratio G. S. to H. S.	42.5
Number of tubes, one boiler, 2-inch	754
4-inch	48
Length of tubes, as fitted, feet and inches	8-02

OFFICIAL TRIALS—*MISSISSIPPI.*

Standardization of Screws.—The vessel was tried by the standardized-screw method, progressive runs being made over the measured mile at the Delaware Breakwater October 16, 1907. From the data obtained on these runs the curves shown on Plate 1 were plotted.

It was determined that 120.45 revolutions per minute of the main engines would give the required true speed of 17 knots. The draught and corresponding displacement at the beginning and the end of the runs were as follows:

	Beginning.	End.
Draught, forward, feet and inches	24-2¾	24-0¾
aft, feet and inches	25-2¼	25-0¾
Displacement, tons	13,040	12,931

OFFICIAL FOUR-HOURS' TRIAL—*MISSISSIPPI.*

On October 17, 1907, the *Mississippi* got under way at the Delaware Breakwater and stood out to sea for the four-hours' full-power trial required by the contract. The weather was clear and pleasant. Calm to light breeze from West to South. Smooth sea. The draught and displacement at the beginning of the trial were as follows:

Forward, feet and inches	24-3⅝
Aft, feet and inches	25-4½
Mean, feet and inches	24-9 1/16
Corresponding displacement, tons	13,124

A synopsis of the data obtained on this four-hours' trial follows:

PERFORMANCE.—FOUR-HOURS' OFFICIAL TRIAL.
MISSISSIPPI.

Steam Pressures. (*Average of one-half hourly observations.*)

	Starboard.	*Port.*
Mean steam pressure at engines, pounds	258.4	265.0
H.P. steam chest gauge, lbs.	246.2	243.75
1st receiver (abs.), pounds	109.0	103.9
2d receiver (abs.), pounds	29.4	22.15
Vacuum in condensers, inches of mercury, mean	25.5	26.4

Temperatures. (*Average of one-half hourly observations.*)

Injection, degrees	59.6	59.0
Discharge, degrees	94.8	98.6
Hotwell, degrees	88.3	91.3
Feed water, degrees	192.8	197.0
Engine room, upper platform, degrees	100.0	100.0
working platform, degrees	89.4	96.4
Firerooms, working level, degrees	95.0	
Smoke stacks, average, degrees	617.0	

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

Average revolutions, main engines, per minute	122.06	122.01
Pumps, main air	22.2	19.8
circulating	177.0	195.4
feed, d. s., per minute	25.4	26.7
fire and bilge	48.0	27.3
Dynamo engines	350.0	
Blower engines	497.9	
Speed of ship, in knots per hour	17.11	
Slip of propeller, in per cent. of its own speed, based on mean pitch	16.45	16.42
Air pressure in firerooms, in inches of water, mean	1.36	

Mean Effective Pressures in Cylinders, in pounds per square inch. (*Averages of cards taken at half-hourly periods.*)

Main engines, H.P. cylinder	99.3	92.6
I.P. cylinder	60.6	64.2
L.P. cylinder	25.0	24.7
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	60.49	60.73

INDICATED HORSEPOWER.

	Starboard.	*Port.*
Main engines, H.P. cylinder	1,459.5	1,361.0
I.P. cylinder	2,458.0	2,605.0
L.P. cylinder	2,750.5	2,726.0
Collective H.P. of both main engines	**13,361.0**	
Air pumps, main	33.0	
Circulating pumps, main	67.0	
Feed pumps, main	135.0	
Auxiliary feed pumps	11.0	
Fire and bilge pumps	18.0	
Forced-draft blowers	192.0	
Dynamo engines	83.0	
Collective I.H.P. main engines, air, circulating and feed pumps	**13,607.0**	
Collective, main and auxiliary engines, in operation	**13,900.0**	

COAL.

Kind and quality used on trial	Pocahontas hand picked.
Pounds, per hour, main and auxiliary engines, during trial	23,525.0

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	18.10
Pounds of coal per I.H.P. per hour, main engines only	1.761
all machinery in operation	1.692
square foot of grate surface, per hour	30.63
Cooling surface (main condenser) per I.H.P., main engine	1.042
Heating surface, square feet per I.H.P. (total)	2.35

TWENTY-FOUR HOURS' ENDURANCE TRIAL—*MISSISSIPPI.*

At 7.00 P. M., October 17, 1907, the twenty-four hours' endurance trial, under all boilers, as prescribed by the contract, was commenced. The weather was clear and pleasant, with gentle breezes from W. by S. The sea was smooth.

The data obtained on this trial were as follows:

PERFORMANCE—TWENTY-FOUR HOURS' OFFICIAL TRIAL.—*MISSISSIPPI.*

Steam Pressures. (*Average of one-half hourly observations.*)

	Starboard.	*Port.*
Mean steam pressure at boilers, pounds	241.7	
Mean steam pressure at engines, pounds	234.5	241.3
H.P. steam chest, gauge, pounds	186.2	178.1
1st receiver (absolute), pounds	52.1	51.8
2d receiver (absolute), pounds	9.71	9.67

Temperatures. (*Average of one-half hourly observations.*)

	Starboard.	Port.
Injection, degrees	59.5	58.6
Discharge, degrees	106.3	104.4
Hotwell, degrees	83.9	80.8
Feed water, degrees	169.6	223.2
Engine room, working platform, degrees	83.4	80.9
Firerooms, working level, degrees	97.7	
Smoke stacks, average, degrees	445.0	

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

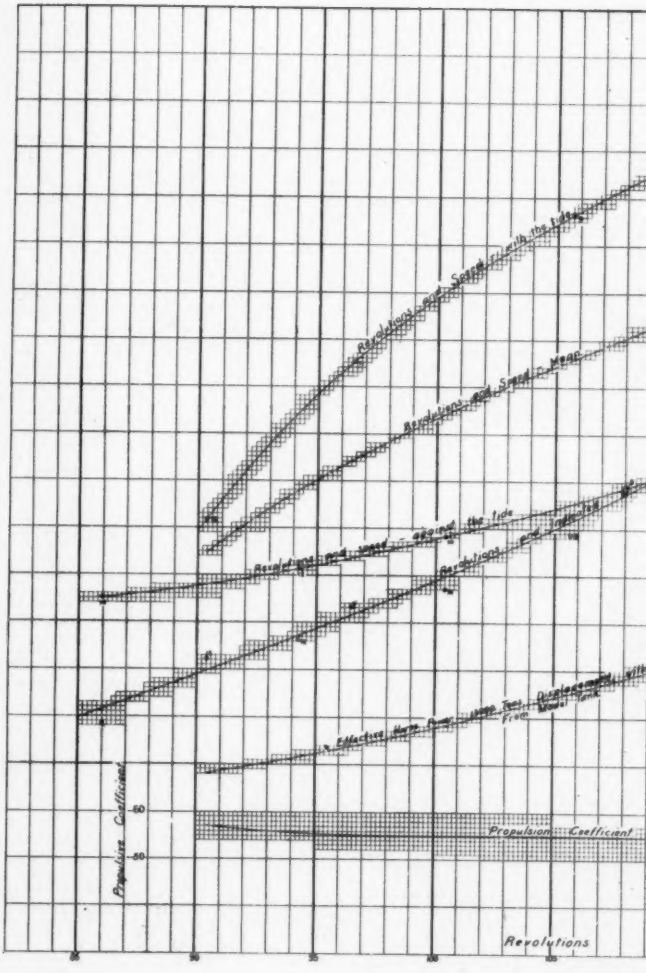
Average revolutions, main engines, per minute	101.54	101.59
Pumps, main air	18.8	17.5
circulating	151.8	146.8
feed, d.s., per minute	20.8	8.4
fire and bilge	31.0	32.7
auxiliary feed	44.4	
Dynamo-engines	350.0	
Blower engines	280.7	
Speed of ship, in knots per hour	15.13	
Slip of propeller, in per cent. of its own speed, based on mean pitch	11.20	11.21
Air pressure in firerooms, in inches of water, mean	0.468	

Mean Effective Pressures in Cylinders, in pounds per square inch. (*Averages of cards taken at half-hourly periods.*)

Main engines, H.P. cylinder	103.5	93.1
I.P. cylinder	34.3	34.9
L.P. cylinder	13.14	13.72
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	40.65	38.96

INDICATED HORSEPOWER.

Main engines, H.P. cylinder	1,287.0	1,136.0
I.P. cylinder	1,157.0	1,173.0
L.P. cylinder	1,207.0	1,255.0
total	3,651.0	3,564.0
Collective H.P. of both main engines	**7,215.0**	
Air pumps, main	34.0	
Circulating pumps, main	36.0	
Feed pumps, main	68.0	
Auxiliary feed pumps	12.0	
Fire and bilge pumps	12.0	
Forced-draft blowers	56.0	
Dynamo engines	83.0	
Collective I.H.P. main engines, air, circulating and feed pumps	**7,365.0**	
Collective, main and auxiliary engines in operation	**7,516.0**	


Revolutions and Speed with the Tides
Revolutions and Speed Mean
Revolutions and Speed around the Ide
Revolutions and Speed
Effective Horse Power
Propulsion Coefficient
Propulsion Coefficient
Revolutions

Pl

No. of Run	Revolutions Mean Both Engines	Speed	I.H.P. Total
1	121.29	17.576	13513
2	123.22	18.240	13561
3	122.10	18.213	13553
4	121.65	18.524	13153
5	120.35	18.409	12868
6	117.61	14.948	11791
7	114.31	17.880	10448
8	108.63	13.941	8979
9	105.64	16.818	7875
10	100.59	13.421	6708
11	96.44	19.255	5454
12	94.23	13.072	4627
13	90.37	12.580	3911
14	85.96	11.764	3043

● Full Power Trial 123.48 17.1402 18765

No. of Run	Revs.	Functions for averages of Revolutions	Speed	Functions for averages of Speed.
1	121.29	x_1 = 121.29	17.576	x_1 = 17.576
2	123.22	x_2 = 244.44	18.240	x_2 = 35.816
3	122.10	x_3 = 367.61 − 122.10	18.213	x_3 = 53.816 − 18.213
4	121.65	x_4 = 489.26 − 243.38	18.524	x_4 = 72.340 − 36.048
5	120.35	x_5 = 609.61 − 120.35	18.409	x_5 = 90.749 − 18.409
		4148.38 / 691.40 (1st Group); 4148.38 / 711.86 (2nd Group)		4148.38 / 1048.38 (1st Group); 4967.670 / 819.292 (2nd Group)
○		122.46; 121.46; 2) 243.91		17.969; 18.317; 2) 36.286
Average in 1st & 2nd groups		121.96	Average in 1st & 2nd groups	18.143

No. of Run	I.H.P.	Functions for averages of Indicated Horse Power
1	13513	x_1 = 13513
2	13561	x_2 = 27132
3	13553	x_3 = 13553 + x_1 = 13553
4	13153	x_4 = x_2 = 26306
5	12868	x_5 = x_3 = 12868
		4134238 / 39195 (1st Group); 4134238 / 39191 (2nd Group)
○		13733; 13107; 2) 26840
Average in 1st & 2nd groups		13411

Dimensions of Propellers

Diameter	16ft 6"
Pitch	19ft 0"
Helicoidal area	735 sq ft
Projected area	68.3 "
Exp. area	.848

U.S.S. IDAHO.
STANDARDIZATION RUNS.
DELAWARE BREAKWATER. DEC 11 1907

BUREAU OF STEAM ENGINEERING
NAVY DEPARTMENT
Washington, D.C. Dec 18 1907

Plate 2.

COAL.

Kind and quality used on trial	Georges' Creek, run of mine.

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	9.796
Cooling surface (main condenser), sq. ft., per I.H.P. (main engine)	1.93
Heating surface, square feet per I.H.P. (total)	4.34

OFFICIAL TRIALS—*IDAHO*.

Standardization of Screws.—The vessel was tried by the standardized-screw method, progressive runs being made over the measured-mile course at the Delaware Breakwater, December 11, 1907. From the data obtained on these runs the curves indicated on Plate 2 were plotted. The weather was generally overcast, with stiff to fresh breeze from W.N.W., moderating somewhat toward the end. There was a moderate sea from W.N.W.

From the results of these runs, with and against the tide, it was determined that 121.86 revolutions per minute of the main engines would be required for a true speed of 17 knots, required by the contract. The draught and corresponding displacement at the beginning and the end of the runs were as follows:

	Beginning.	End.
Draught, forward, feet and inches	24-4¼	24-2½
aft, feet and inches	25-8¼	25-5½
Displacement, tons	13,248	13,105

OFFICIAL FOUR-HOURS' TRIAL—*IDAHO*.

On December 12, 1907, the *Idaho* got under way at 6·30 A. M. for the official four-hours' trial, as prescribed by the contract. The weather was fair, with a stiff breeze from W.N.W. The sea was moderate at first, increasing to rough near the end of the trial. The draught and displacement at the beginning of the trial were as follows:

Forward, feet and inches	24-0½
Aft, feet and inches	25-7
Mean, feet and inches	24-9½
Corresponding displacement, tons	13,093

The data obtained on the four-hours' trial were as follows:

PERFORMANCE.—FOUR-HOURS' OFFICIAL TRIAL.—*IDAHO*.

Steam Pressures. (*Average of one-half hourly observations.*)

	Starboard.	*Port.*
Mean steam pressure at boilers, pounds	278.0	
at engines, pounds	255.0	255.0
H.P. steam chest gauge, pounds	247.0	261.0
1st receiver (absolute), pounds	131.6	131.9
2d receiver (absolute), pounds	45.5	44.1
Vacuum in condensers, inches of mercury, mean	27.3	26.4

Temperatures. (*Average of one-half hourly observations.*)

Injection, degrees	48.9	50.2
Discharge, degrees	104.3	105.2
Hotwell, degrees	115.5	111.3
Feed water, degrees	208.2	199.6
Engine room, working platform, degrees	86.9	84.0
Firerooms, working level, degrees	85.5	
Smokestacks, average, degrees	65.2	

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

Average revolutions, main engines, per minute	123.62	123.34
Pumps, main air	25.7	40.1
circulating	173.4	168.0
feed, d.s., per minute	25.6	32.4
fire and bilge	...	28.0
auxiliary feed	...	20.1
sanitary	...	10.4
Dynamo engines	350.0	
Blower engines	454.0	
Speed of ship, in knots per hour	17.14	
Slip of propeller, in per cent. of its own speed, based on mean pitch	17.35	17.16
Air pressure in firerooms, in inches of water, mean	0.93	

Mean Effective Pressures in Cylinders, in pounds per square inch. (*Averages of cards taken at half-hourly periods.*)

Main engine, H.P. cylinder	96.9	96.2
I.P. cylinder	62.8	62.9
L.P. cylinder	26.2	25.1
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	62.4	61.1

INDICATED HORSEPOWER.

	Starboard.	*Port.*	
Main engines, H.P. cylinder	1,426.0	1,441.0	
I.P. cylinder	2,583.0	2,579.0	
L.P. cylinder	2,803.0	2,933.0	
total	6,812.0	6,953.0	
Collective H.P. of both main engines			**13,765.0**
Air pumps, main			18.0
Circulating pumps, main			52.0
Feed pumps, main			150.0
Auxiliary condenser, air and circulating pumps			5.0
Fire and bilge pumps			4.0
Auxiliary feed pumps			25.0
Forced-draft blowers			168.0
Dynamo engines			80.0
Sanitary pumps			2.0
Collective I.H.P. main engines, air, circulating and feed pumps			**14,010.0**
Collective, main and auxiliary engines in operation			**14,269.0**

COAL.

Kind and quality used on trial	Pocahontas, hand-picked.
Pounds per hour, main and auxiliary engines, during trial	27,100.0

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	18.59
Pounds of coal per I.H.P. per hour, main engines only	1.969
Pounds of coal per I.H.P. per hour, all machinery in operation	1.898
square foot of grate surface, per hour	35.29
Cooling surface (main condenser), square feet per I.H.P. (main engines)	1.035
Heating surface, square feet per I.H.P. (total)	2.287

TWENTY-FOUR HOURS' ENDURANCE TRIAL—*IDAHO*.

The official twenty-four hours' endurance trial, under all boilers, as prescribed by the contract, was commenced at 3.00 P. M., December 12, 1907. The weather was fair and pleasant, with moderate breezes from W.N.W. There was a moderate sea.

The data obtained on this trial were as follows:

PERFORMANCE.—TWENTY-FOUR HOURS' OFFICIAL TRIAL.—*IDAHO*.

Steam Pressures. (*Average of one-half hourly observations.*)

	Starboard.	*Port.*
Mean steam pressure at engines, pounds	245.2	252.3
H.P. steam chest, gauge, lbs.	202.2	209.3
1st receiver (abs.), pounds	66.8	71.4
2d receiver (abs.), pounds	27.9	21.3
Vacuum in condensers, inches of mercury, mean	27.9	28.2

Temperatures. (*Average of half-hourly observations.*)

Injection, degrees	46.6	46.9
Discharge, degrees	77.7	87.4
Hotwell, degrees	96.4	106.3
Feed water, degrees	204.8	208.4
Engine room, working platform, degrees	79.0	
Firerooms, working level, degrees	90.0	
Smoke stacks, average, degrees	525.0	

Revolutions, or double strokes, per minute. (*Average of one-half hourly observations.*)

Average revolutions, main engines, per minute	104.06	104.06
Pumps, main air	24.2	24.2
circulating	153.0	156.0
feed, d.s., per minute	14.8	16.4
fire and bilge	22.0	27.6
auxiliary condenser, air and circulating	20.8	
Dynamo engines	350.0	
Blower engines	280.4	
Speed of ship, in knots per hour	15.14	
Slip of propeller, in per cent. of its own speed, based on mean pitch	13.72	13.72
Air pressure in firerooms, in inches of water, mean	0.4	

Mean Effective Pressures in Cylinders, in pounds per square inch. (*Averages of cards taken at half-hourly periods.*)

Main engines, H.P. cylinder	109.6	106.1
I.P. cylinder	33.7	32.6
L.P. cylinder	13.0	13.0
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	40.1	39.0

INDICATED HORSEPOWER.

Main engines, H.P. cylinder	1,378.0	1,330.0
I.P. cylinder	1,178.0	1,135.0
L.P. cylinder	1,228.0	1,227.0
total	3,784.0	3,692.0

Collective H.P. of both main engines	**7,476.0**
Air pumps, main	14.0
Circulating pumps, main	29.0
Feed pumps, main	58.0
Auxiliary condenser, air and circulating pumps	4.0
Fire and bilge pumps	3.0
Forced-draft blowers	62.0
Dynamo engines	121.0
Sanitary pumps	1.0
Collective I.H.P. main engines, air, circulating and feed pumps	**7,577.0**
Collective, main and auxiliary engines in operation	**7,768.0**

COAL.

Kind and quality used on trial.....Mixed, run of mine.

DEDUCED DATA.

I.H.P. (total) per square foot of grate surface	11.48
Cooling surface (main condenser), sq. ft., per I.H.P. (main engine)	1.862
Heating surface, square feet per I. H.P. (total)	4.19

FEATURES OF A BATTLESHIP DESIGN.

By Lieutenant H. C. Dinger, U. S. Navy, Member.

As the subject of the design of new battleships, especially the design of the new all big-gun 20,000-ton battleship for the U. S. and foreign navies, is a matter very much discussed, I have thought that the setting forth of some important features that might be obtained in a new ship, and illustrating these by means of rough-sketch plans drawn approximately to scale, might be of considerable interest. It might also serve to call attention to certain important features which it might be advantageous to incorporate into new designs, and which have, in many cases, not been realized to the fullest extent.

The sketch plans are not complete, nor are they intended to be so. They are merely a rough and approximate outline upon which a detailed design could be based, and are intended to show ideas of general characteristics which might be modified or elaborated upon in various directions.

The aim of this paper has been to bring up certain new possibilities and to create discussion and service criticism of various features that should be embodied in the best possible fighting vessel that can be built on a displacement of less than 20,000 tons.

Some of the primary matters that should influence the design are:

To obtain everything with the least weight and space essential to the best possible operation and utility.

To arrange everything so that it can be operated and taken care of by the least possible personnel, both in officers and men.

To arrange everything so that all operations, work, etc., done, can be accomplished with the least possible labor.

To discard everything that is not definitely in a large measure essential to the fighting capacity, power and utility in time of war.

To make all parts as easy and cheap of manufacture as it is possible, while not detracting from their efficiency or adaptability.

To give to each item weight, space and other considerations in a proper proportion to their relative value as contributors to the total fighting power.

To make everything as simple as possible.

The target displayed in broadside should be as low as possible, and all top hamper that will, when struck, cause shell to explode, should be reduced to the very lowest possible limit.

All guns should be placed in such positions that they can be fought in any kind of weather.

The forecastle of the vessel should be sufficiently high to prevent seas from coming on board at high speeds or in rough weather.

QUESTION OF SPEED *VERSUS* BATTERY.

Speed is a valuable quality for offense and for defense, but its value is problematical; in some cases it may be of great use, in others of but little. Battery power is of certain and definite value and always has a definite utility. In fleet actions the speed of the combined fleet will not be very high, nor is it necessary. When speed will be wanted it will be needed to concentrate on certain parts of the enemy or to pursue an enemy. This can be accomplished by having a portion of the fleet of high speed. The problem then seems best to be solved by having a larger portion of the battleships of the fleet of moderate speed, say not over 18 or 19 knots, and of large battery power and ammunition supply; and then, also, to have a smaller proportion of high-speed battle-

ships of same protection, but with less battery power (though guns are to be of same caliber), less ammunition and less coal. These faster vessels would be preferable as flagships.

CHARACTERISTICS OF MODERATE-SPEED BATTLESHIPS.

We will first take up the requirements of the moderate-speed battleship. It may be assumed that the displacement will be 17,000 to 18,000 tons, and with this displacement the following general distribution of weight might be made:

	Tons.	*Full load.*
Hull and fittings	6,200	
Armor	3,800	
Protective deck	800	
Machinery, including water	1,800	
Battery and ammunition	1,800	2,000
Equipment	1,000	
Coal, normal	2,000	2,500
Total	17,400	18,100
Length, feet		490
Beam, feet		82
Draught, feet		25–26
I.H.P.		20,000
Speed, knots		18.5 to 19

As excessive speed is not necessary and as it costs too much to obtain it, a speed equal to or slightly in excess of that of our existing battleships is sufficient. All possible power that can be obtained on a certain allotment of weight should be secured, and the machinery should be the most economical in coal consumption that it is possible to secure.

It is perhaps possible by great care in design, especially with regard to matters tending to the highest possible economy in steam consumption, to secure machinery on 1,800 tons' weight that will enable this vessel to obtain a speed of twenty knots. It may also be remarked that although the turbine engines of the *Dreadnought* show a considerable advantage in economy at high speeds over existing vessels of our Navy, it is quite possible to build reciprocating engines that will be more economical than the turbine engines have shown themselves to be. The water consumption of 14 pounds of water

per indicated horsepower per hour can be equaled and even beaten by reciprocating engines when they are built so that they will utilize more nearly all means tending to economy which are now known to be practical for marine work.

BATTERY ARRANGEMENT.

The latest opinion of the best informed is that the main battery should consist of the greatest number of the heaviest guns that the vessel can carry. Assuming that the displacement is 17,000 to 18,000 tons, the weight that can be allotted to the battery will be something below 2,000 tons. A battery of ten 12-inch guns can be installed on about 1,500 tons. If we allow 300 tons for a battery of rapid-fire guns the total weight of battery can be set at 1,800 tons.

The arrangement adopted for the *Michigan* for four two-gun turrets on centerline gives the best possible arc of fire for these eight guns. Having placed eight of the guns in this way, positions for the other two guns must be found. If they are placed in two turrets, one on each side, as on *Dreadnought*, these guns can have an arc of fire of 180 degrees, but all of the large guns cannot fire on either broadside. A fifth turret can be placed on centerline, and with this arrangement all of the heavy guns can fire on either broadside, and by arranging the superstructure properly the after guns will be able to fire within a few degrees of dead ahead.

With the arrangement shown on sketch plan, we will have a fire of ten 12-inch guns on each broadside, and to about 20 degrees from ahead, and four 12-inch directly ahead or astern. The 12-inch guns will be placed at such commanding heights that no difficulties in rough weather need be feared.

The secondary battery should consist of a limited number of 5-inch guns, about ten. These guns would be for primary use in action against the unprotected parts of the enemy and, in combination with a few smaller saluting guns located under the forecastle, against torpedo attack.

These 5-inch guns should be of the greatest range and

muzzle velocity that can be attained with this caliber; and their mounts should have all possible attachments for securing great rapidity and accuracy of fire. They should either be well protected by armor that will keep out splinters and which cannot be penetrated by the secondary battery of a possible enemy, or they should be unarmored.

There is some question as to the advisability of providing armor for the secondary battery. Some very weighty opinion is against using any armor for the secondary battery. If any armor is fitted it should be at least 5 inches thick. The fitting of light armor, 2 or 3 inches, is generally objectionable. If the armor for the secondary battery is left off, the weight, about 400 tons, can be utilized for other purposes. The main belt could be increased over an inch in thickness with this weight. The guns should be installed so that they all have great arcs of fire and so that all can be fired in rough weather.

In deciding upon the battery, the aim should be to get in as many guns as can be carried on the weight and to secure for each of these guns a maximum arc of fire. If the increase in number decreases the arc of fire of any of them to a considerable extent, then fewer guns should be installed.

In arranging the battery on this design it has been the aim to secure the very greatest arc of fire for every large gun installed. As arranged, each 12-inch gun will have an arc of fire of about 300 degrees, and all 12-inch guns can fire through an angle of about 120 degrees on either beam. The 5-inch guns are arranged so that at least three out of the nine can fire in any direction, and six can fire on either beam. They all have an arc of fire of about 130 degrees. They are arranged in two groups, so as to facilitate their fire control, ammunition supply and protection. The ammunition for all the guns is supplied directly from the magazine-handling room to the gun or gun-handling room, and requires no double handling. This is a most important matter in connection with the rapidity with which ammunition can be supplied.

It does not appear advisable to increase the number of large guns beyond ten. If more are added they would have to be placed on one side of the ship and their arc of fire would be decreased. To secure room for another turret on the center line, the vessel would have to be lengthened to such an extent that the displacement would be materially increased.

MACHINERY.

If reciprocating engines are used the machinery should consist of two 4-cyl. triple-expansion engines, $\frac{32'' \times 50'' \times \text{two}75''}{48''}$ designed to work with 275 pounds of steam at throttle and give about 20,000 I.H.P. Special provision should be made to have the engine clearances reduced as much as possible and to have large L.P. exhaust pipes and ample condensing surface so that a good vacuum may be obtained in the L.P. cylinder when running at full power. Feed-water heaters specially arranged to secure the highest feed temperature from the auxiliary exhaust steam should be fitted. There should be twelve water-tube boilers having about 1,200 square feet of grate surface. Boilers to be fitted with superheaters. Forced-draft blowers, with electric drive, capable of producing an air pressure of three inches of water, should be supplied, and these should be located on the deck above the boiler rooms, but arranged so that the speed can be regulated from the fire-room. The main feed pumps should be located in the engine rooms, and should be fitted with steam-regulating valves for automatically keeping a constant excess pressure in the feed line. Ash ejectors should be provided. Extraordinary measures should be taken to provide the greatest possible ease and facility for operating and overhauling all machinery. If sufficient data has been obtained concerning the economy and reliability of steam turbines to prove their superiority over naval reciprocating engines of the present date, then turbines should be installed. If they are installed it should be with the idea that they are to be the motive power for all battleships built in the immediate future. The superior advantages

should, however, first be proven to compensate for the sacrifice presented in a lack of uniformity and the use of machinery unfamiliar to the present naval personnel. It might be advisable to install a combination of turbines and reciprocating engines on three screws. The center screw would have a turbine of about half total power and the two wing screws would have reciprocating engines. Such a combination would probably lead to greater economy at cruising speeds than the all-turbine arrangement.

COALING.

Some changes ought to be made from our present arrangements for coaling, and in arranging the bunkers for supplying coal to the fires. The coal must be capable of being taken on board rapidly, and it should be possible to cart it quickly from one chute to another. It should be possible to coal without interfering with the battery or the living quarters of the crew. One of the most serious defects in some late U. S. battleships is the coaling arrangement. Coal must be hoisted above the boat deck and then lowered through hatches to the linoleum-covered gun deck, on which are located the 7-inch guns, each separated by an armored bulkhead. On this deck the coal is put into chutes which lead to the bunkers. During the period of coaling the men having quarters on the gun deck have no place to eat and sleep, and in cold weather this is a serious matter. Also, while coaling and for several hours after, until things can be cleaned up, the guns on the gun deck are not ready for use.

The bunkers must be arranged so that there is about the same amount of coal available for each boiler. On some recent vessels the forward boilers are accessible to coal for only about two days' steaming, while abreast others there is an abundance.

The coal from the upper bunkers should be capable of being sent to the fireroom without opening the lower bunkers. This is provided for in the latest designs by having chutes leading from the upper bunkers and opening into the

firerooms. By this arrangement the lower bunkers can be kept closed in action. This ensures better protection against damage by torpedoes. By using coal from above the protective deck the stability of the vessel is maintained in better shape.

In the sketch plan it will be seen that there are five double lower bunkers on each side and six upper single bunkers on each side, making thirty-two bunkers in all. Each group of main bunkers will have two permanent filling chutes which extend to the main deck, there being portable chutes between upper and berth decks. These chutes should be amply large, at least two feet in diameter. By this arrangement of coaling, the coal can be put into the bunkers with the least possible disturbance to other parts of the ship. The crew's quarters and battery is in no way interfered with, and there is ample room at the openings to handle and dump the bags or buckets in which the coal is hoisted.

WATERTIGHT SUBDIVISION.

The latest practice is to provide no doors whatever in the transverse bulkheads between the several boiler rooms and engine room. In order to get from one compartment to another it is necessary to go up about 30 feet through various decks and then down again. Under these conditions it is impossible to have proper supervision of the machinery, and dangerous accidents are very likely to occur. These boxed-in engineer departments will have a terrible time when maneuvering in squadron at anything near full power.

The latest types of watertight doors are quite reliable, and the need of decent communication between the various parts of the engineer department is so great and all-important that the prohibition of all doors in transverse bulkheads probably creates greater defects than the one it is designed to remedy. The extreme importance of being able to manipulate the machinery of a naval vessel with facility and exactness is, I fear, somewhat overlooked in the design which contemplates the omission of doors. The idea seems to be to get machinery of

a certain power in somehow. Matters that affect the possibility of it being readily handled too often receive only casual attention. If the machinery is installed so that it can be operated and overhauled with ease, full power and efficient service can be relied upon, but if installed so as to be difficult to operate it cannot be depended upon and the best results will not be obtained.

CONNING TOWER.

The present conning towers are so small, cramped and crowded with all manner of instruments, that in battle they would be practically useless for the purpose for which they are intended, namely, to furnish an armored position from which the commanding and navigating officer can observe and give directions for the handling of the ship in action. The conning tower should consist of an armored tube 12 to 15 feet in diameter, its base to be protected by armor from the protective deck up, and it should extend to a height of 6 or 7 feet above the highest mounted turret. The top of the tower should be open, and the first interior platform should be about 5 feet below the upper edge of the tower. There should be other platforms below, arranged at convenient heights, and on these and in the armored compartments about the base of the tower should be installed, in suitable groups with reference to each other, the wheel, engine telegraph, helm indicator, battle-order and range transmitters, voice tubes, telephones, apparatus for making signals, wireless station, etc.

Directions given by the commanding, navigating or fire-control officer could be passed to the operators stationed below by word of mouth or by telephone. The instruments of transmission and the operators would be thoroughly protected, and the directing personnel could remain on the upper platforms of the tower and be well protected yet capable of observing all parts of the vessel and have a clear view in any direction. All charts, diagrams, plans, etc., that are likely to be used during action should be accessible to the commanding, navigating and ordnance officers. Hence a portion of the space should be arranged for the convenient filing of such informa-

tion, which would consist of charts and navigating instruments, tactical information, information concerning enemies' vessels, gunnery instructions and ordnance data and any other information likely to be consulted during action.

A light bridge, supported by a metal frame, could be built out on either side of the tower. This could be utilized when specially needed, as in handling the ship alongside the dock. It is extremely important to cut down the enormous amount of top hamper that is being gathered around the bridge and conning tower of our late battleships. This great amount of truck, a great deal of which is inflammable, is an invitation to disaster in time of battle.

POSITIONS FOR RANGE-FINDING STATION AND STATIONS FOR FIRE-CONTROL OFFICERS.

This is a subject widely discussed by officers serving on armored vessels. Opinions differ very widely as to details, but all agree that special provision is necessary for these matters, and it should be embodied in the design of new vessels.

It would seem that the range-finding stations should be in an elevated position, and in one that had at least some protection. On present vessels range finders are mounted in tops without any protection. The range finders might be placed in elevated, small, armored casemates 10 or 12 feet in diameter, having armor several inches thick. The casemates should be supported by a skeleton framing stiff enough to prevent excessive vibration and designed so that a large part of the support could be shot away and still keep the range tower standing. Such towers would furnish about the nearest thing that our present knowledge would indicate to fulfill the requirements of a range-finding station.

The fire-control officers could have their stations in the same armored top, their directions to be sent by portable telephone or voice-tube system, either direct to the battery or to an operator placed in a well protected position below; this operator to communicate directions from fire-control officers to the battery.

In order to provide an alternate armored position for the fire-control officers in a position different from that of the range finders or that from which the ship is handled, an after armored tower might be fitted.

This tower could be arranged in a similar manner as the conning tower forward, but it could be smaller. From it would be operated such instruments of transmission as are necessary for communication between the fire-control officer and the battery.

In case the fire-control officers are stationed in the tops, this after tower could be used as an observation tower, or as a place from where the vessel might be directed in case an unlucky shot or explosion should wreck the forward tower. The principal instruments necessary for the handling of the vessel could be duplicated in the after tower.

To avoid the danger of having splinters from the supports of the mast falling on top of the armored tower it would be more advantageous to move the masts some distance from the conning tower, as shown in sketch plan, than to have these masts directly over the bridge and conning tower, as has been the practice in most battleships.

The arrangements for communicating from the fire-control officers to the battery must be separate and distinct from the system of general communication throughout the ship. The exact details of this system will, however, depend upon the system of fire control that is developed and adopted. In order that certain important structural matters may be arranged for this purpose, it is necessary to know definitely the general essential features of the fire-control system to be used. When the basic principles and elementary matters as to the method of handling the ship in battle is definitely decided upon, then all structural matters, to carry this out, should be furnished, and the development of these arrangements should not be compromised by the interference of other matters that are not as essential to the fighting efficiency.

If a height of about 65 feet is considered a sufficient elevation, the best position for the range-finding station would

seem to be just forward and abaft the smoke stacks and about 10 feet below the level of the top of stack. In this position the interference from smoke is done away with. If the stations are located at a height just above the top of the smoke stacks, smoke will interfere at some time or another, especially in action, when courses are frequently changed and forced draft is being used.

If, on the other hand, it is found necessary to have the range-finding and fire-control station at a higher elevation, say 100 feet above water line, then this station will have to be raised and the smoke stacks shortened so that their tops are at least 25 feet below the fire-control station.

In the sketch plan, sheets 1 and 2, the two positions for fire-control station are shown. In case the high station, shown in dotted lines, is used, the tops of smoke stacks would reach only to O.

ARMOR.

The purposes of armor may be divided as follows: (1) To protect the heavy gun positions. (2) To protect the magazines and ship's vitals. (3) To protect the vessel's flotation by keeping the water line intact. (4) To protect the secondary battery and other important equipment about the decks. (5) To protect the directing personnel in battle.

The heavy guns are protected by heavy turrets and barbettes; armor 12 to 9 inches thick is proposed. The vitals are protected by the protective deck and by the side armor. The armor to protect the water line, and thus the floating power of the vessel, should be a complete belt, thick enough and extensive enough to prevent any dangerous puncture at or near the water line. If it is not a complete belt its efficiency is seriously impaired, since a shell striking the unarmored part will at once destroy the integrity of the water line.

For these reasons the water-line belt should be complete. Forward and aft it can be made slightly thinner than amidships. Armor 10 inches thick is contemplated for the thick-

est part of the belt, to be thinned to 6 inches at bow and stern. The belt should be about 12 feet high, the part extending below the water line to a distance of 4 feet can be gradually thinned to 6 inches. With this arrangement the upper edge of belt will be about 7 feet above the water line when ship is fully loaded. When light, the lower edge of belt will be about 2½ feet below water line. If the belt is too high it can always be lowered by filling some of the double bottom compartments; so that it is more advisable to have the belt too high than too low.

The armor for protecting the secondary battery, if fitted, is to form a casemate around the 5-inch guns, as shown, and be 6 inches thick. This armor not only protects the secondary battery, but also to a great extent the ventilators, smoke-stacks, blowers and other equipment located on main and berth deck. For 320 feet amidships the main belt will have a maximum thickness of 10–11 inches. At the ends of this armor there will be diagonal armor 8 inches thick connecting the side armor to the barbettes of the forward and after turret. Forward and aft of the magazines the armor will be 6 inches thick. The belt will extend to the level of the berth deck, which will be armored.

Each smoke stack is to be individually protected by 6-inch armor, as shown, to extend from berth deck to above boat deck. The space between this armor and the smoke stack proper is to be utilized as an air shaft for ventilating the orlop-deck passage and as a means of supplying air to those forced-draft blowers that are located on the center line. The purpose of this armor about the smoke stack is to guard against shells piercing the base of stack or exploding there. This armor will insure a certain amount of natural draft for the fires, and will also guard against the disastrous results of having the smoke from the boilers coming on to the various closed decks of the vessel, which is what will happen when the base of an unarmored stack is pierced by a shell or fragment.

Smoke stacks should also be made in bolted and flanged

sections, so that in case they are struck, they will break at the section and not, as was the case with many Russian ships, bring down the whole stack.

The armored conning tower is to have 8-inch armor from the level of the 5-inch gun casemate to the top. Diagonal armor is to be fitted at the forward ends of forward 5-inch gun casemate to protect the various decks from a raking fire from forward.

To protect against under-water damage by torpedoes, an extra longitudinal bulkhead is worked in on each side, separating the inboard and outboard coal bunkers. This bulkhead should be extra strong so as to be able to withstand the shock of an explosion. The outboard bunkers would be filled through a chute at the top and emptied through doors opening into inboard bunkers. In action these doors would be kept closed, and outboard bunkers preferably full of coal. The corresponding compartments on opposite sides of the vessel should be connected by pipes to enable the vessel to be kept upright in case a large compartment on one side is damaged.

PROTECTIVE DECK.

The protective deck should protect from a plunging fire and from splinters and fragments. It would appear that the proper place for the armored deck would be at the upper level of the armor belt. As shown in plans, the armored deck in connection with the side armor forms an armored box which primarily protects the water line, and guards against any punctures that would tend to destroy or injure the vessel's floating power. It also protects the machinery and magazines from shells. At the water line there is a curved watertight deck, which is primarily for strength and subdivision, but also serves as a splinter deck.

It is believed that this arrangement of armored decks offers better protection than where there is an armored deck at the level of the bottom of the armored belt. The armored deck, as arranged, will stop the effect of plunging shot one deck height sooner, and the lower watertight deck will serve to

catch any splinters or fragments. The arrangement also gives a greater and more extensive protection to the machinery and the magazines.

ARMORED POSITION FOR WOUNDED IN BATTLE.—OPERATING ROOM BEHIND ARMOR.

Most vessels built are not provided with a well-protected place where the wounded in action may be placed and looked out for. Operating rooms are very often in unprotected parts of the ship that would become uninhabitable in a close action. In the sketch design it will be noticed that the operating room is behind thick armor, and a portion of the sick bay is also behind armor.

On the center line, immediately above the curved watertight deck, well protected by armor and also by coal bunkers, there is a wide passage which contains the forced-draft blowers. The smoke stacks run through the center, and the boiler-room hatches and ventilators are at the side. This space is to be fitted up, where available, with tiers of bunks. Under ordinary circumstances this is to be the berthing space for the firemen. Here the firemen, coming off watch, may be able to get some needed rest in peace and quiet—a matter quite essential to securing an efficient fireroom force. In time of battle it will be a good place to bring the wounded to, and it will be convenient to the operating room. This space can be well ventilated, since there are plenty of hatches running through it, and it will be no hotter than the ordinary berth deck. From this space can be operated all the boiler-room valve-lifting gear, such as for boiler-stop and safety valves, main drain, fire-main and fire-extinguishing valves. This gear in many of the present vessels is placed so that it interferes with the handling of the battery. From this space communication with any boiler room, engine room, evaporator room or machine shop is readily secured, and it forms a thoroughly-protected passage from one end of the ship to the other. Voice tubes, electric mains, etc., can be led through this space and be kept in accessible positions.

CLEAR SIDES AND UPPER DECKS.

As will be seen, the main deck will be clear of all obstructions from the ship's side to the deck houses located on the center line, which contain offices aft, boat and deck stores, tanks for oils, galleys, bakery and bread room in the center, and blacksmith shop and laundry forward. In action this deck can be kept well clear, the only guns mounted on it are the 5-inch well forward. The clear deck gives a good open space as a lounging place for the men, enables a better supervision over the crew to be obtained, gives a good place for conducting drills and the very best facilities for handling lines or boats, getting on stores, etc. It makes one end of the ship accessible to the other. Around the sides of the deck houses could be located hammock nettings and small lockers for deck gear and fittings.

STORE ROOMS.

One of the most laborious jobs on board ship is the getting in and out and the shifting of stores. The arrangement and location of the storerooms will materially affect the amount of this work. Storerooms are often put in any old place left over from other uses. A thorough investigation of the uses to which various storerooms are put, and an effort to put them where they will best serve their purposes, would bear startling results in increased ease in handling and keeping stores and increased capacity for stowing them. When a ship is designed the question of the location and arrangement of storerooms must be considered. Storerooms must be located so as to secure the least handling of the matters that are to be stored in them. Storerooms that are being constantly used should be in accessible positions, and the best possible facilities for getting the stores in and out should be provided.

In the sketch plans an attempt has been made to indicate, in a general way, the location of the principal storerooms in the most convenient places for their use. It will be noticed that the bread and flour rooms are near the bakery, provisions are near the pantries and galleys where they will be used.

Boat stores, blocks, tackles, lines, cordage, etc., are provided on the upper deck near where these matters are to be used. Engineer and electrical storerooms are arranged so as to be handy to the engineer department and dynamo room. The main engineer storerooms are accessible to both the engine and the fireroom. The gear and stores for engineer and dynamo storerooms, machine shop and evaporator room can be lowered down the engine hatch. In the forward and after part of the vessel the space between the berth and orlop deck, 7 to 9 feet high, is available for stores. This space is accessible through hatches in the berth deck.

There should be certain storage spaces arranged so that different character of stores could be carried in them at various times. Thus they could be arranged so that they would be available for either coal, ammunition or provisions, and they could then be used for whichever article was the most important to carry at any one time. At certain times it may be extremely necessary to carry an extra supply of ammunition, at other times extra stores, and again it may be an extra amount of coal that is most needed. In the sketch design it is contemplated that the large bunker spaces abreast the engine rooms and the forward dynamo room may, when occasion demands, be utilized either for magazines or stores.

GALLEY, PANTRY, ETC.

The best location for the galley and bakery is naturally on the upper deck, where the fumes of cooking and baking and the unpacking of boxes of provisions and the handling of other culinary gear will interfere the least with the living quarters ar[illegible]e battery.

The pantry should be on the deck having the crew's messes, and it is suggested that the pantry, and not the galley, be made the serving-out place. As arranged in sketch plan the pantry is directly under the galley, and dumb waiters should be fitted connecting the two. In order that hot drinks and certain other dishes may be kept warm after they have been served out to messmen, there should be a number of small

electric heaters about the mess deck upon which the food after leaving the pantry could be kept warm until the time it is to be eaten. It is contemplated that all the crew messing will be on the same deck as the pantry, which fact should tend to facilitate and improve the serving of the food.

Adjacent to the galley there should be lockers or small store rooms, where culinary supplies, in constant use at the galley, should be kept and stored. This should include a great many dry and wet provisions, which are now generally kept in holds or storerooms beneath the protective deck and which require a great deal of time and trouble to break out. There should also be a space fitted up as a butcher shop where the meat could be cut and prepared for cooking. Sufficient space for these accessories could be found in the spaces assigned the galleys and bakery in the sketch plan.

COLD STORAGE AND REFRIGERATORS.

A great improvement in these matters would be effected if a portion of the cooling chambers were arranged as ready or thawing rooms, where meat and provisions about to be used could be kept and drawn from as needed. The main storage rooms would only be entered once a day or once in two days, a certain supply of meat, etc., taken out and then placed in the ready rooms, from where it can be taken as needed. The fitting of these ready rooms would allow a great many of the large portable ice chests, now supplied, to be discarded.

In the sketch plan such ready-refrigerating rooms are indicated on the berth deck forward, near the scuttle butts, immediately above the ice machines. The location is convenient to both the pantry and the galley. Trap doors should be fitted through berth deck into refrigerating chambers so that they could be filled through these, instead of fetching it below and putting the large pieces of meat through small side doors. Much closer stowage would be possible in this way.

WINCHES AND BOAT BOOMS.

Winch and crane machinery should be reduced as much as possible, and where possible should be placed where it might be protected by armor. In many of the present designs all the boat and crane motors are in very much exposed positions on the upper and bridge deck. In any close action these machines would not only be dismembered by shell, but the fragments from the machines are likely to cause serious damage to the surrounding personnel and equipment and the guns of the secondary battery. It is possible to arrange it so that the crane motors and many of the coaling hoists can be located lower down, where the splintering effect would be less. Some of these machines might be placed behind armor. A portion of the coaling hoists should be made portable and arranged so as to be temporarily secured to the deck whereever the special conditions of coaling would secure the best leads. If this were done, the number of coaling hoists fitted on board might be reduced to some extent. When the vessel is cleared for action such portable hoists could be placed in a position where they are not likely to interfere with the battery or the personnel. It would be a military advantage to dispense with the turntable type of boat crane now in use, and install instead boom derricks supported from the masts. The lines could be handled by certain winches, which, like the booms, could also be used for coaling. By doing this a great deal of top-hamper and shell-catching gear might be avoided without any loss in working efficiency.

SEARCHLIGHTS.

The searchlights can be mounted in the upper tops of the masts, or on platforms on the skeleton masts. They could be fitted with electric controlling gear so that they can be operated from below. It might also be an advantage to have arrangements provided whereby they could be lowered in the day time in case an action is likely, and hoisted to their position at night. This would greatly lessen their chances of

being shot away. To work in combination with these elevated searchlights there should be portable searchlights mounted on specially designed carriages, which could be moved to any desired position on the main deck and operated from there. This would seem to be the solution of the searchlight problem.

HIGH-SPEED BATTLESHIP.

To secure a high-speed battleship the allotment of weight will have to be modified so as to get more weight for machinery. This can be done only by cutting down proportionately on something else. The principal weights that may be reduced are the battery, ammunition and coal. Some slight reduction may be possible in equipment weights. On a weight of 2,500 tons, machinery capable of developing 35,000 I.H.P. can be built. To get this weight the following allotment might be made.

	Tons.	*Full load.*
Hull and fittings	6,400	
Armor	3,800	
Protective deck	800	
Machinery, including water	2,500	
Battery and ammunition	1,300	1,500
Equipment	900	
Coal, normal	1,600	2,200
Total	17,300	18,100
Length, feet		510
Beam, feet		80
Draught, feet		25–26
I.H.P.		35,000
Speed, knots		24 to 25

This would call for a reduction in main battery to eight 12-inch guns and a considerable reduction in ammunition and coal. The speed would be from 24 to 25 knots. The lines of the vessel would be finer, the length greater and the beam slightly less. The removal of the middle turret would allow for the increased space necessary for the machinery. The increase in boiler power would require sixteen boilers, making it necessary to have another boiler room and smoke stack.

The decrease in beam would reduce the bunker space, as would also the increase in width of boiler room necessary to accommodate larger boilers.

The armor should be arranged in the same manner and be of the same character and thickness.

Such a fast battleship would have the same resisting power and her battery would have the same range as that of the other battleship. There would simply be an exchange of additional battery for speed.

This vessel could be used to bring an enemy into an engagement, to concentrate on a weak point, to pursue a fleeing enemy, and in general to utilize whatever advantages the possession of speed might at any time have. Vessels of this character, in the proportion of one to four for the total number of battleships, would seem to be a real, sound compromise between speed and gun power.

These vessels would differ from the present armored cruiser in that they have the same armor protection and hence a resisting power equal to that of a battleship. They have the same caliber and range for their big guns as the ordinary battleship, and hence can engage at the same range as the battleships. They are thus in every way qualified to take their position in the fighting line.

BATTLESHIP WITH HEAVIER GUNS.

Another matter for consideration in the design of the best type of battleship is the question of whether it is advisable to use a gun larger than the 12-inch for the main battery.

There are some who advocate the use of larger-caliber guns, 13 or 14-inch of 40 or 45 calibers in length. The advantage that these guns will have is the increased range and increased power of penetration at long ranges. It is argued that the ships armed with these heavier guns would be able to knock out the vessel armed with the 12-inch gun before the latter could get within effective range. Of course, the use of the larger gun would mean a reduction in number and also some reduction in rapidity of fire.

No high-powered guns of these larger calibers have as yet been built for naval work; but, of course, that does not mean that they cannot be built. There would, however, probably have to be considerable experimenting before a thoroughly successful large gun would be developed.

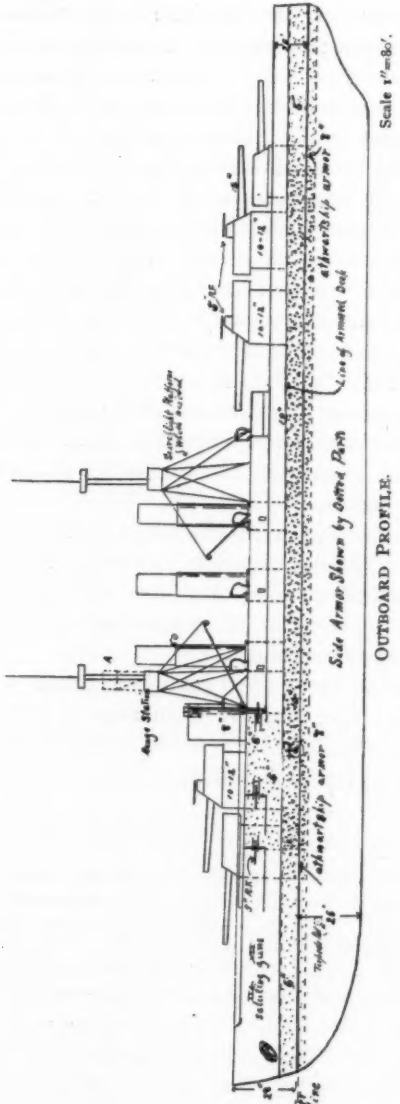
If it should be considered more advisable to use 13 or 14-inch guns, the arrangement of battery suggested would be eight guns in four turrets on the center line, placed in same general positions as on sketch plan, sheet 6. The general arrangement of vessel and secondary battery would be approximately the same as shown for the design with 12-inch guns.

Granting that the larger-caliber gun will weigh 30 per cent. more than the 12-inch, eight of the larger guns, with their ammunition, can be installed on 1,500 tons weight. The four turrets will weigh about the same as the five smaller turrets. The armor and structure of the ship would be about the same as before.

A fast battleship, with the larger-caliber guns and same displacement, would have six guns mounted in three turrets, one forward and two aft. Six guns with ammunition can be installed on 1,300 tons. This would allow 2,600 tons weight to be allowed to machinery.

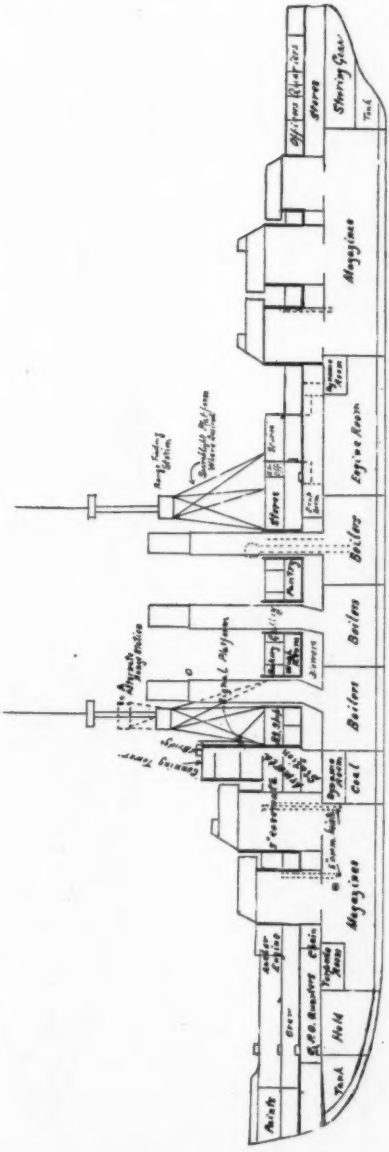
On the other hand, a fast battleship could be built to carry eight of the larger guns by an increase of about 15 per cent. in the displacement, which would allow an approximate distribution of weights, as follows:

	Tons.
Hull	7,500
Armor	4,000
Protective deck	1,000
Machinery	2,800
Equipment	1,000
Battery and ammunition	1,800
Coal, normal	2,000
Total	20,100



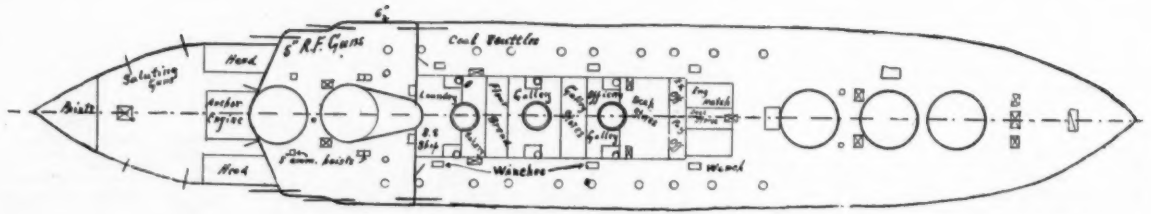
OUTBOARD PROFILE.

Sheet 1.



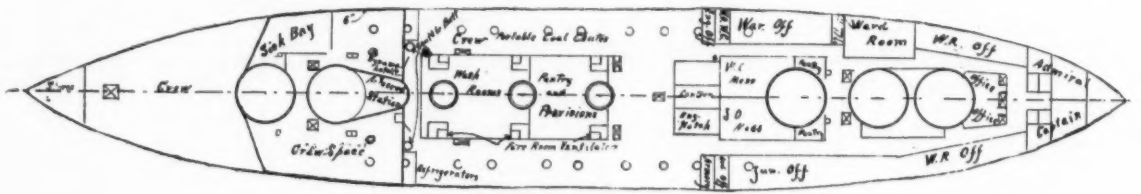
INBOARD PROFILE.

Sheet 2.



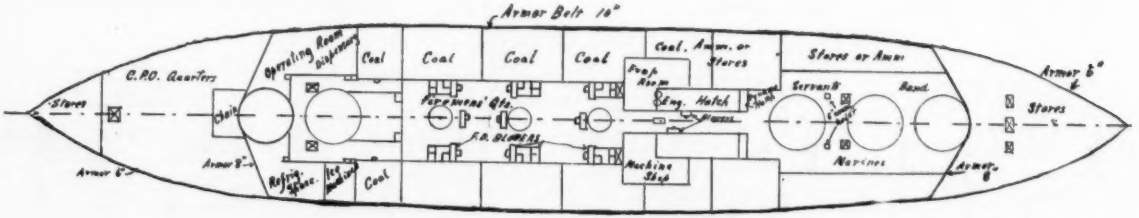
MAIN DECK.

Scale 1"=80'.

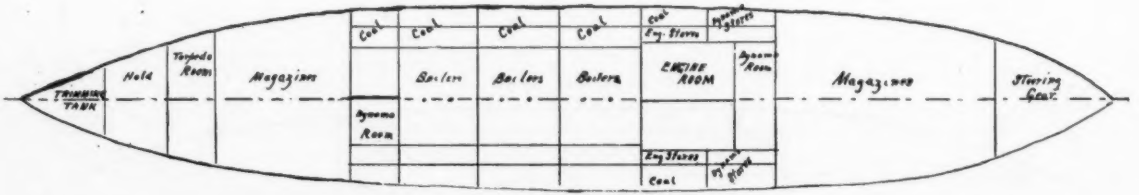


BERTH DECK.

Sheet 3.

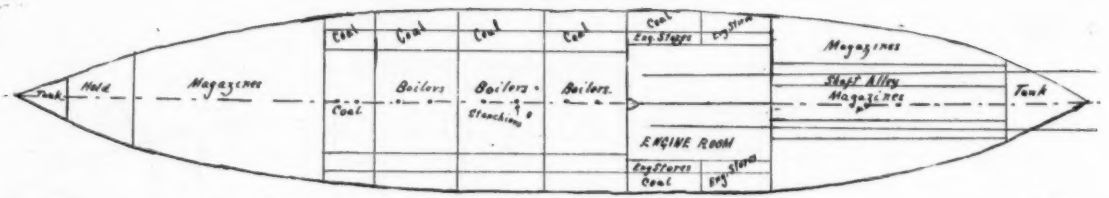


ORLOP DECK. Scale 1"=8o'.

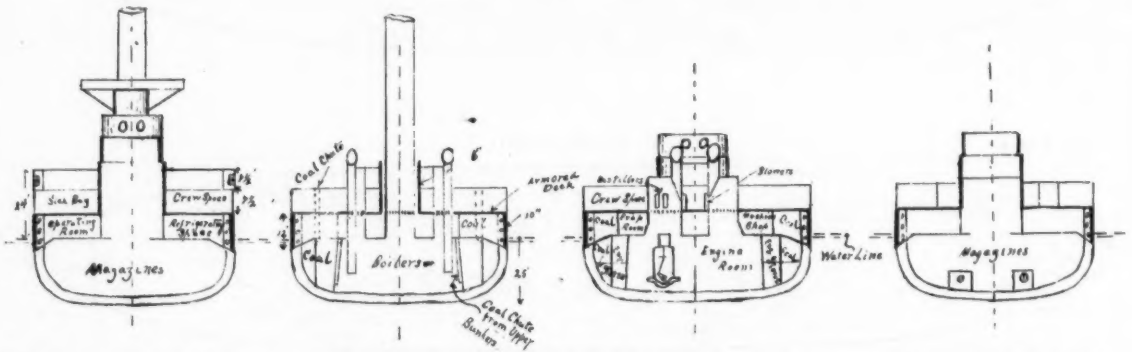


UPPER PLATFORM.

Sheet 4.



LOWER PLATFORM. Scale 1″=80′.



SECTION AT FORWARD TURRET, LOOKING AFT.

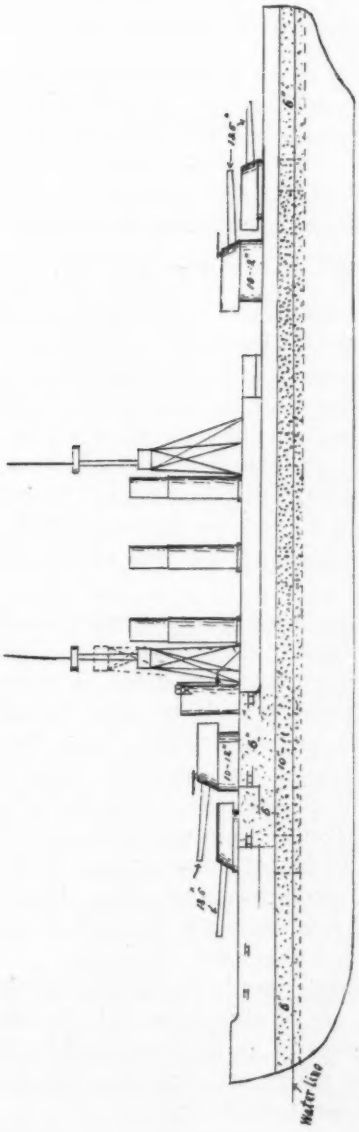
SECTION AT FORWARD SMOKE STACK, LOOKING AFT.

SECTION AT FORWARD PART OF ENGINE ROOM, LOOKING AFT.

SECTION AT 4TH TURRET, LOOKING AFT.

Sheet 5.

Sheet 6.



B. S. WITH GUNS LARGER THAN 12-INCH.

NOTES.

LIQUID FUEL FOR INTERNAL COMBUSTION ENGINES.

By R. W. A. Brewer, A. M. Inst. C. E.

Since the gas engine was a commercial machine, the advantages of the use of a liquid fuel for driving this type of engine became apparent, and at the present time these advantages have become so enormous that there is quite a likelihood of the liquid-fuel internal-combustion engine superseding a large proportion of the steam units now in use. Manufacturers are designing and building these engines in constantly increasing sizes, and it is, perhaps, still a debatable point whether large marine engines of this type can be successfully used or not.

Liquid fuels must not be considered solely as the products of petroleum, because the control of that market is in the hands of a very few large companies. It is necessary to have one or more alternative fuels, in order that purchases of fuel can be made in an open market. It is, therefore, essential that engines designed for liquid fuel should be capable of being run on these alternative fuels without material alterations in their gear. The manufacture of a national fuel, as distinct from an import from foreign countries, should receive every encouragement, as such a fuel could not be a monopoly, and it is reasonable to expect that its price would be maintained at a steady and low figure.

We have recently seen how a great and concerted effort to encourage the use of alternative fuels has had the effect of reducing the price of a petroleum product, which points to the fact that at the present time the prices demanded by the large oil companies are false ones.

ATTEMPTS TO UTILIZE THE HEAVIER OIL.

In order to successfully utilize a liquid in the form of oil in the cylinder of an internal-combustion engine, two distinct methods have been tried to cope with the difficulties present. The fuel can be introduced:

1. As oil, *without* chemical change, either in an atomized or partly vaporized and partly atomized form.

2. *With* chemical change, such that the oil before entering the cylinder has been wholly or partially decomposed into the lighter hydro-carbons.

In the first group may be classed the first commercially successful engine, the Priestman, although in its effect it borders on case two. Distinct from this type is the Diesel engine, which works by compressing the air alone up to about 700 pounds per square inch. Into this highly compressed air at the end of the inward stroke of the piston is injected the correct proportion of liquid fuel, by means of air at a higher pressure operating a jet. As this fuel enters the cylinder it burns spontaneously, without a sudden rise of temperature, throughout a greater part of the working stroke.

Finally, there is the Roots type of engine, which has the low or ordinary compression of about 70 pounds per square inch, in which each charge of oil is accurately measured, and injected into the engine cylinder during the suction stroke, and in which chiefly atomization is relied upon to produce proper carburation of the air in the cylinder.

Under type 2 come all engines having externally-heated vaporizers, in which the liquid fuel is first converted, by partial decomposition, into a gaseous or semi-gaseous state before its introduction into the engine cylinder. A chemical change takes place in this vaporizer, and there is always the likelihood of deposits of carbon or heavy residuals forming here. Any possible variation in temperature between the vaporizer and the induction pipe will cause the vapor to condense in the pipe or round the inlet valve before it reaches the engine.

THE SOURCES OF SUPPLY AND THE QUESTION OF PRICE.

As far as we in this country are concerned at the present time, the United States of America can be almost ignored as a source of supply for the petroleum fuels. Originally, practically all the lighter distillates of petroleum imported into this country were obtained from the Pennsylvanian fields, as there was only a small percentage of petrol in the Russian oil, our other source of petroleum at that time.

Now the home consumption of American spirit has reached such proportions, together with the depletion of the wells in that country, that the amount available for export is very small. Whereas in 1905 we imported 10½ million gallons of petroleum spirit from America out of a total of 18½ million gallons, this importation had fallen to 2½ million gallons for the first six months of 1907, a decrease to less than 20 per cent. of the total amount imported.

The great increase in the demand for petroleum spirit in this country is shown by the following figures supplied by Mr. Alexander Duckham:

	Imperial gallons.
Year 1904	11,972,000
1905	18,658,000
1906	26,792,000

and the percentages of imports from the different sources have been as follows:

Country.	1904 Per cent.	1905 Per cent.	1906 Per cent.
United States	50	56	29.8
East Indian group	37	42	61.4
Roumania	8.2	0	8.6
Other countries	4.8	2	0.2
	100	100	100

These figures show the change in the sources of supply during the last few years, which change is still more marked for 1907.

Russian oil contains practically none of the lighter fractions which have been used in the past for motor spirit. Also

the labor disturbances in Russia account for its absence from the above list.

Roumania, on the other hand, does a large export trade in spirit, the bulk of which goes to France and Germany.

Roumanian Spirit obtained, in gallons.

	Gallons.
1903	14,500,000
1904	18,600,000
1905	23,500,000

The bulk of the spirit now coming into this country is from the fields of Sumatra, Borneo and the East Indies, and it is only within the last few years that the companies operating these fields have exported their light products to Europe. The oil from these fields contains a large percentage, up to 20 per cent. of a spirit distilling between 60 degrees C. and 150 degrees C., and referred to by the author as Borneo spirit, and also a considerable quantity of the more familiar Shell spirit, having a specific gravity of 0.715 to 0.720. The amount of spirit available from these fields depends upon the market for kerosene and other residuals. Sir Marcus Samuel in a recent speech stated that although they could produce an enormous quantity of spirit, "the price would depend upon whether they could find remunerative markets for the other products left when the petrol was removed from the crude."

As these products constitute something like 90 per cent. of the total, there is very little assurance that the petrol market will continue in a stable condition for any length of time. The price obtained for the residuals is primarily governed by the price of coal; for instance, Russia at the present time utilizes the bulk of its production locally as fuel oil. It would not pay to distil this oil for the sake of a small percentage of petrol. The removal of the specific-gravity standard might make the necessary difference, as far as Russia is concerned, whether it would pay to distil or not.

Considering the East Indian oil, in addition to the demand for fuel oil, which is very small, the chief marketable residual is kerosene. The companies, however, find this market decreasing year by year.

FLUCTUATIONS IN THE PRICE OF PETROLEUM.

As compared with other fuels petroleum products show unaccountable fluctations. This is undoubtedly due to the fact that the control of supplies is in very few hands. It is, therefore, an easy matter to create artificial prices, which must be paid by the consumer. Users of liquid fuels of the heavier types know how difficult it becomes to enter into any sort of contract for supplies, and that when sums of money have been expended in fixing apparatus for burning heavy liquid fuels, the price of such a fuel is raised until no economy results in return for the change.

As regards the lighter fractions, some idea of the fluctuation in price can be gathered from the following list of prices to agents in London, for spirit delivered in cans and cases:

	Per gallon. *Pence.*
November, 1904	7
November 20, 1905	8
January 19, 1906	9
February 21, 1906	9½
May 3, 1906	10
August 2, 1906	12
December 24, 1906	13
July 26, 1907	12

The final reduction of one penny occurred simultaneously with the issue of the report of the Fuels Committee of the Motor Union.

This serious rise in price has proved almost disastrous to users of commercial and public vehicles, particularly motor omnibuses, in connection with which the margin of profit is so small. The larger companies have contracted for supplies at a low figure, but the early contracts are now expiring. All the later contracts have been made at higher figures, and whilst the earnings remain the same, the profits must decrease.

This all points to the necessity of healthy competition in the fuel market, and several alternative fuels have been suggested for use in a high-speed internal-combustion engine.

When we look for a substitute for petrol, a home-produced fuel, which can be utilized without in any way altering the existing arrangements of the engine or carburetter, undoubtedly holds out great hopes. Such a fuel, known as benzol, is a distillate of coal tar, or can be extracted from coal gas. It is a light hydro-carbon, C_6H_6, and is a clear liquid similar in appearance to petrol, but having a slight smell of sulphur, due to the presence of about 150 grains of sulphur compounds per gallon. The specific gravity of pure benzol is 0.885; boiling point 80 degrees C. or 176 degrees F.

Total evaporation point of crude benzol is 145 degrees C. or 293 degrees F. and 1 gallon contains 163,680 British thermal units of heat, as against 157,142 B. T. U. for petrol, and has an explosive range from 2.7 to 6.3 per cent.

The largest source of supply is from coke ovens or gas works.

In the modern systems of coke manufacture for iron smelting the by-products obtained in the distillation of coal are collected instead of being allowed to go to waste, as in the old style of beehive oven. The benzol obtained in the gases from distillation is readily absorbed by means of suitable oils, from which it is afterwards extracted by distillation.

Commercial "90 per cent. benzol" is a spirit of which 90 per cent. evaporates in a retort at a temperature of 120 degrees C., and the production of which amounts to about 5,000,000 gallons per annum in this country. This supply could be largely increased by the installation of suitable recovery plant, should the demand warrant the expenditure. The supply could thus be doubled within a very short time. The present price of this fuel when refined is about 9d. to 10d. per gallon at the makers' works, the process of refining and washing costing about 1d. to 2d. a gallon. The process of washing by means of sulphuric acid and soda partially eliminates the sulphur compounds, but unwashed benzol might be made suitable for motor-car work by distilling out the lighter portions, and with them the bulk of the impurities.

EXPERIMENTS WITH 90 PER CENT. BENZOL.

With regard to the use of 90 per cent. benzol as a motor fuel, the author has made a number of experiments, the results of some of which are given below, and can be compared with those for petrol of various densities.

	Miles per hour.	Distance.	$\frac{EV^2}{C \times 100}$	V
Long Test.				
Benzol, sp. gr. 0.875..	27.2	116 miles	14.8	1
Short Tests.				
Benzol, sp. gr. 0.875.....	24	14 miles	12.25	in traffic.
Benzol, sp. gr. 0.875.....	22	15 miles	12.4	in traffic.

The distances traveled per gallon compare very favorably with the best results obtained with petrol, viz:

0.715 specific gravity, 18 miles per gallon.
0.760 specific gravity, 21.5 miles per gallon.

The engine pulled well, and the speed of the car was kept about the same as when using petrol.

The author finds that on some occasions it is advisable to use rather a larger jet with benzol than with petrol, but care must be taken to admit sufficient air, or sooting takes place inside the cylinder. The smell of the liquid in the unburnt state is slightly more noticeable in the case of benzol, but the exhaust gases have little smell and no tendency to smoke.

In spite of what has been said against alcohol as a motor fuel, it is the author's opinion that alcohol has great possibilities in this direction. A clear statement is given in the Report dated July, 1907, of the Fuels Committee of the Motor Union as to the requirements and behavior of this fuel and to the high compression necessary to obtain the best results.

ALCOHOL AS A FUEL.

The author has obtained samples of commercial methylated alcohol having a specific gravity of 0.833, and with them conducted a number of tests, using other ingredients in varying proportions. He has succeeded in running his motor car sat-

isfactorily upon these mixtures and also with alcohol mixed with only 25 per cent. of another fuel.

The fact is here stated in order to refute many biased opinions which have been expressed of late as to the impracticability of alcohol as a fuel for this purpose. Sir Marcus Samuel, in the speech previously referred to, remarked with reference to alcohol: "Although alcohol might prove an excellent bogey with which to attempt to frighten the producers of petrol, they did not entertain the smallest misgiving that this spirit could ever become a competitor to their petrol, for the simple reason that it did not contain those qualities essential for the running of motor vehicles."

Considering now these essential qualities, the properties of alcohol may be briefly summarized as follows: Ethyl alcohol C_2H_6O, a volatile colorless liquid with a specific gravity of 0.806 at 0 degree C. Calorific value about 12,600 B. T. U. per pound. Boiling point 78 degrees C. Explosive range 4 to 13.6 per cent. with air.

Methylated spirit, consisting of 90 per cent. ethyl alcohol and 10 per cent. methyl alcohol (CH_4O), has a calorific value of about 11,000 B. T. U. per pound.

The following is an approximate comparison:

	Petrol 0.722	Methylated spirit
Calorific value in B.T.U. per lb.....	20,000 (gross)	11,000 (gross)
Net calorific value per lb., *i. e.*, heat converted into work.....	4,248 B.T.U.	3,322 B.T.U.
Thermal efficiency =.....	21 per cent.	30 per cent.

Heat converted into work=Calorific value.

In practice, a petrol motor rarely exceeds a thermal efficiency of 18 per cent., whilst with an alcohol motor the highest efficiency is readily obtained, and, considering that a gallon of alcohol weighs about 12 per cent. more than that of petrol, the net value per unit volume is about the same. A great advantage of alcohol is its uniformity of composition, the whole of the spirit distilling over at a temperature of about 78 degrees C.—"Page's Weekly."

ON THE INDICATED POWER AND MECHANICAL EFFICIENCY OF THE GAS ENGINE.

Paper read before the Institution of Mechanical Engineers, October 18, 1907, by Professor BERTRAM HOPKINSON, Member of Cambridge University.

In the report of the Committee of the Institution of Civil Engineers on "The Efficiency of Internal-Combustion Engines,"* the following remarks occur (page 247):

"It would be desirable but for one circumstance to calculate the relative efficiency only from the indicator horsepower. But it appears that in the case of gas engines, and especially gas engines governed by hit-or-miss governors, the indicator diagrams do not give as accurate results as is generally supposed. The diagrams vary much more than those of a steam engine with a steady load, and the mean indicator horsepower, from the diagrams taken in a trial, may, it appears, differ a good deal from the real mean power."

This statement is fully borne out by the tests of the Committee, which show that the mechanical efficiency taken as the ratio of brake to indicated power varied from 80 per cent. to 94 per cent. in the three engines tested. These engines were of similar type, but of different sizes, and whereas the smallest, of 5 horsepower, showed a mechanical efficiency of 90 per cent., the intermediate engine, of 20 horsepower, showed a lower efficiency, of 80 per cent. The Committee remarked that these values were obviously incorrect, and the values adopted by them for the mechanical efficiency were obtained by running the engine light and making an estimate of the indicated horsepower under these conditions. Assuming that the mechanical loss is constant at all loads, the indicated power at full load can be determined by adding the power absorbed at no load to the brake power. The mechanical efficiencies of the three engines found in this way were respectively:

Engine	L	R	X
Mechanical efficiency	0.86	0.866	0.888

* Proceedings of the Institution of Civil Engineers (1905-6), Vol. lxiii.

These results are just what would be expected; the mechanical efficiency showing a slight improvement with the size of the engine.

The opinion of the Committee quoted above is obviously important and may be expected to have a widespread effect in gas-engine testing. It throws doubt upon many of the efficiency tests on gas engines which have hitherto been made and published. Moreover, the method which the Committee themselves adopted for getting the indicated power from the brake power seems to require further investigation before it can be accepted as accurate. It may no doubt be assumed on the evidence of steam-engine tests that, under given conditions of lubrication, the friction is practically independent of the pressure in the engine. But whereas in the steam engine the whole of the mechanical losses are to be ascribed to friction, that is not the case in the gas engine in which a considerable amount of power is wasted in pumping, and is usually included in the mechanical losses. Moreover, with a given supply of oil, lubrication conditions in the steam engine are practically constant, but in the gas engine that is by no means the case. Great changes can take place in the temperatures of the cylinder walls in a comparatively short time, and this will affect the viscosity of the oil, and therefore the work spent in friction. The author, therefore, determined to undertake an investigation with the object of finding whether the indicator power of the gas engine does, in fact, vary so much, and is so difficult of determination, as the report of the Committee referred to suggests. If it were found that the indicated power could be accurately determined directly, it was further desired to test, by direct comparison of brake and indicated power, the validity of the Committee's method of getting the mechanical efficiency. Briefly, the conclusions reached are:

1. If precautions are taken to keep the pressure of the gas supply constant, the diagrams given by the engine are remarkably regular, and, whether the engine be missing ignitions or not, it is possible, by the use of a sufficiently accurate indica-

tor, to obtain the indicated power from diagrams within 1 or 2 per cent. It seems probable that the difficulty experienced by the Committee was due either to the essential defects, for this purpose, of the ordinary form of indicator, or to casual variations in the gas supply per suction, due perhaps to variation in the gas pressure at the engine.

2. The difference between indicated horsepower and brake horsepower is rather less than the horsepower at no load under the same conditions of lubrication, mainly because of the difference in the power absorbed in pumping. In the particular engine tested by the author, the error from this cause in obtaining the indicated power would amount to about 5 per cent. The friction is substantially constant from no load to full load, provided that the temperature of the cylinder walls is kept the same, but the influence of temperature is very great.

The engine used in the tests was kindly placed at the author's disposal by Messrs. Crossley Brothers. It is intended to give a maximum output of 40 horsepower on the brake, and the following are the particulars of it:

Cylinder, 11½ inches in diameter by 21-inch stroke.

Speed, 180 revolutions per minute.

Compression space, 407 cubic inches.

Compression ratio, 6.37.

Compression pressure, 175 pounds per square in, absolute.

When exploding every time, the indicated horsepower at 180 revolutions per minute is 0.495 times the mean effective pressure.

The engine works on the ordinary Otto cycle, governed by hit-and-miss. The ignition is by magneto. The engine was loaded by belting it to a dynamo (lent by Messrs. Mather & Platt), which also served to motor it round when required. The fuel used was Cambridge coal-gas. When an accurate measurement of brake power was desired all round rope-brakes were used, one on each flywheel; and as the measurements were such that the brake tests only lasted a few minutes, it was not necessary to use any water cooling. The engine was fitted with an exhaust gas calorimeter of the spray type.

For measuring the gas supply a standard holder by Messrs. Parkinson & Cowan, having a capacity of 10 cubic feet, was placed between the main gas supply and the engine, and as close as possible to the latter. In the ordinary running of the engine the holder stood at a constant level, the flow of gas into it just balancing the flow out, and under these conditions it served as a gas bag, coming down by about one-tenth of a cubic foot at each suction of the engine. In a measurement of gas consumption the supply to the holder was cut off, so that the engine took gas only from the holder, and the quantity taken in a definite number of suctions (usually about 50) was noted. The indicator diagrams were photographed at the same time as this measurement was made. After the completion of the measurement the inlet pipe to the holder was opened, and the counterweights adjusted, so that the holder slowly rose to nearly its highest position, when the measurement could, if necessary, be repeated. It was possible in this way to read off the gas consumption correct to one part in 500, and, allowing for possible inaccuracies in the gas-holder divisions, small changes in temperature and pressure, etc., it may be taken as certain that the gas consumption given is within one-half per cent. of the truth. This method of gas measurement is, of course, especially adapted for cases like the present, in which the actual gas used in a particular cycle or series of cycles is desired; but it may be noted that it is almost equally suitable for the measurement of gas consumption for a long period. It was found that it made no perceptible difference to the power given by the engine whether the inlet pipe to the holder was open or closed, and it may be assumed, therefore, that the gas consumption remains the same under these two conditions. The rate of consumption determined by the holder may therefore be assumed to hold during the intervals when the holder is filling, or is standing at a constant level. This method of measurement, which is much superior in accuracy to any meter, and is very convenient, might easily be applied to much larger engines, since all that is required is a holder of capacity sufficient to run the engine for about one minute.

The work of making the tests and reducing the results was done almost wholly by two students of the engineering laboratory—Messrs. A. R. Welsh, of Trinity College, and A. L. Bird, of Peterhouse. To these gentlemen the author must express his thanks. Without their assistance it would have been impossible for him, with the time at his disposal, to have carried through the series of tests which is here described.

The first requirement for the investigation proposed was an accurate indicator. In order to get at all satisfactory results, it was necessary to construct an instrument which could be relied upon absolutely to give the indicated power within 2 per cent. Further, it was necessary that the instrument should be capable of working for long periods without breaking down, so that large numbers of diagrams could be taken under given conditions. The author's experience of indicating gas engines has convinced him that it is quite impossible to fulfil the first of these conditions, to say nothing of the second, with any form of pencil indicator. It is unnecessary to discuss here the various sources of error in the pencil indicator, but it may be noted that two of them—namely, the inertia of the piston and looseness in the joints—are of especial importance in the gas engine. In the engine on which the experiments here described were made the pressure rises on explosion from 170 pounds to 500 pounds, or 600 pounds per square inch in less than .01 second. Now, the natural period of oscillation of a Richards indicator of the kind made by Cassartelli, of Manchester, for gas-engine work, when working with a three-hundred spring, is of the same order—that is, about .01 second. In consequence of this, as is well known, violent oscillations may be set up by the explosion, and continue along the expansion line of the indicator. The magnitude of these oscillations depends upon the relation between the time taken by the pressure to rise to its full value and the period of oscillation of the indicator. Thus with certain gas charges there may be practically no oscillation, while with a slightly different mixture the oscillations may become so great as to make accurate measurement of the diagram impossible. The effect of indicator

inertia on gas-engine diagrams is well known; but the other defect referred to—namely, backlash in the mechanism—has not, I think, been fully appreciated, though it is fairly obvious. The maximum pressure in a gas engine in which the compression ratio is 6 to 500 pounds to 600 pounds per square inch, and it is necessary therefore to use a very stiff spring. Stiffness is also required to reduce the natural period of the instrument, and so to bring within reasonable limits the oscillations due to inertia. In practice the author has found that in the Crosby indicator a spring giving a deflection of 1 inch with a pressure of 300 pounds per square inch is barely stiff enough. Now, the mean pressure is about 100 pounds per square inch, giving a mean height with this spring of 0.3 inch; slackness in the joints amounting to a total movement of the pencil of .01 inch will therefore cause an error in the diagram area of 3 per cent.

The author has examined a considerable number of pencil indicators for backlash, and has not yet succeeded in finding one, even when perfectly new, in which it amounts to less than 1.5/100 inch, and in very few is it less than .02 inch, giving an error of 6 per cent. in the diagram area. It is by no means surprising that this should be so when one considers that in the Crosby indicator motion there are four pin-joints between the piston and the pencil, and that the motion is magnified six fold. Thus a movement of .01 inch at the pencil corresponds to only 1.24/100 inch at each joint. Another error of the same kind is that due to the deformation of the lever carrying the pencil set up by friction of the pencil on the paper. The combined effect of this and of backlash is to increase the mean height of the diagram by an amount which, from the nature of the case, is quite uncertain, but which may easily reach 1/30 inch even with a new indicator in perfect adjustment. This error is in most instruments counter-balanced to some extent, and in many overbalanced, by that due to motion of the pencil at right angles to the piston bore.

The pencil motion should, of course, be accurately parallel to the piston motion, but in all indicators looseness in the joints

prevents this motion from being perfectly definite. The pencil can move anywhere between two parallel lines, and the friction between pencil and drum is quite sufficient to make it take either of these. In the diagram, the expansion line and compression line are both shifted inwards, and the area and mean pressure reduced. This defect is sometimes rather serious in the Crosby indicator, which in other respects is as good as a pencil indicator can be for gas-engine testing. The author has never found it amount to less than .02 inch, and the mean pressure taken with this instrument is, in consequence, often too small. Using a three-hundred spring the mean pressure taken from a diagram 2½ inches long from a gas engine compressing to 170 pounds per square inch absolute will be 3½ per cent. too small if the horizontal backlash amounts to .02 inch. Stretching of the chord caused by drum friction of the kind discussed by Professor Osborne Reynolds acts in the same way. It would appear that on account of these disturbances, in themselves so minute, gas-engine diagrams taken with a pencil indicator cannot be relied upon as accurate to within 5 per cent., and the error must often be more like 10 per cent. When the indicator is subjected for any considerable time to the wear and tear involved in recording the explosions of a gas engine with high compression and using heavy charges, its joints rapidly become so slack as to destroy its value for any but the roughest measurements. Indeed, it may almost be said that the life of a pencil indicator (as an instrument of precision) when used on such a gas engine is limited to a few hundred explosions.

To overcome both these defects of inertia and backlash, it is necessary to reduce very much the motion of the moving parts of the indicator, and to use optical means for magnifying that motion. The diaphragm manograph first proposed by Perry, and now in use to some extent as a commercial instrument in the form of the Hospitallier-Carpentier manograph, is unsuited for accurate quantitative work, for a number of reasons, the chief of which are that the displacement is not proportional to the pressure, so that the diagrams cannot be inte-

grated by a planimeter, and that it is inconvenient to calibrate. The author therefore determined to get a new design of indicator of the piston-and-spring type with optical magnifying mechanism. In the form finally adopted, after a considerable amount of experimenting, the spring consists of a straight piece of steel strip held as an encastred beam in a steel frame. A piston slides in a bore communicating with the engine, the axis of this bore being at right angles to the spring and passing through its center. The pressure on the piston deflects the spring, and so tilts a small mirror about an axis at right angles to the bore, the pivots of this mirror being carried on a steel frame. To give the other motion to the mirror the whole apparatus (straight spring and mirror with its pivots) is positively connected to an eccentric on the crank axle, by which it is rocked about the axis of the bore, thus giving the piston motion of the diagram without the possibility of any lost motion. This instrument is practically indestructible, and it has been left open to the engine for considerable periods without giving it any attention. The vertical deflection is accurately proportional to the pressure, so that the diagrams can be integrated with a planimeter. Finally, the period of oscillation is only about 1/700 of a second with such strengths of spring as were used in the mechanical efficiency tests. The indicator is very easily calibrated by dead weights. The diagrams used in these measurements were photographed; but for many purposes it has been found sufficient to observe them direct by means of a telescopic arrangement by which they are projected as a bright line of light on to a transparent screen with vertical and horizontal scales. It is easy to plot the diagram on to a piece of squared paper, and its area can thus be obtained within 5 per cent. without the trouble of photography.

Fig. 1 is a facsimile of a normal diagram taken with this instrument; it represents about a dozen consecutive explosions. In order to determine the accuracy with which the indicated power can be determined, three diagrams similar to this were taken, each comprising twenty consecutive explosions, and these were integrated by separate observers directly from the

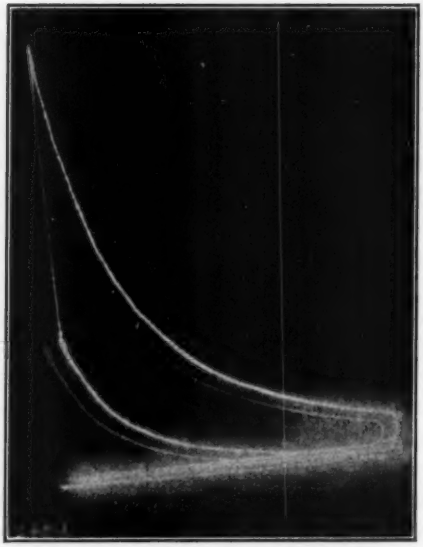


Fig. 1.—Facsimile of Normal Diagram Representing About a Dozen Consecutive Explosions, Taken with Indicator, Figs. 4, 5.

negatives, each diagram being dealt with by two observers, so as to get six independent integrations. In the result the mean of all the measurements was found to be 0.954, the maximum being 0.963, and the minimum 0.940.

This test was considered to have established the accuracy of the instrument, subject to the calibration being correct. It also proves that the diagram, when the engine is exploding continuously, is quite remarkably regular. It is certain that in a continuous series of, say, a hundred explosions the diagram area does not vary more than 1 per cent. on either side of the mean value. When the governor cuts out charges of gas, however, a slight enlargement of the diagram is sometimes perceptible in the cycle following a miss. Occasionally this enlargement amounts to as much as 4 per cent., while at other times it disappears completely. On theoretical grounds it is to be expected that the gas taken after a miss will be, if any-

thing, slightly less than after an explosion. On the other hand, the efficiency is slightly higher. But whatever the cause of the slight difference in area, it is clear that it can have no practical effect in an ordinary full-load trial, since it only happens once in five or six cycles. It may therefore be taken as definitely established that, given a sufficiently accurate indicator and constant conditions, the indicated horsepower of a gas engine may be determined from diagrams with an accuracy which is probably superior to that attainable in the steam engine.

The indicated horsepower of the engine is dependent, of course, upon the gas supply. In the tests described above the amount of gas taken per cycle was, no doubt, very constant, but it is probable that under certain circumstances there may be casual variations of gas supply which give rise to varying diagrams. The gas taken per suction with a hit-and-miss governor is determined by the temperature of the cylinder walls and piston and by the opening of the gas cock. So long as these variables and the pressure in the mains are kept constant there is no reason why the gas consumption should vary. In the trials described in this paper a gas holder of considerable capacity was placed close to the engine, and the pressure in the holder was, no doubt, very nearly constant; but that, of course, may not be so in all practical tests. The mean pressure in the cylinder during the suctioin stroke is about 2 pounds per square inch below atmosphere, equivalent to about 55 inches of water. A variation of 2 inches or 3 inches of water in the pressure outside the engine, therefore, gives a substantial change in the gas supply. Such a variation would naturally occur after a missed ignition, if the gas bag were not of very ample capacity and placed close to the engine, and this may to some extent account for the very considerably enlarged diagrams which in some engines have been observed to follow a miss.

Changes of cylinder temperature considerably modify the gas consumption per cycle with the same opening of the gas cock, but these changes are, of course, comparatively slow, and

do not affect the accuracy of an estimate of indicated power where the conditions are fairly constant. As an indication of their amount the following test may be cited. The engine was first run light with a large flow of jacket water; it was then fully loaded and the jacket water throttled until the temperature at exit rose to 185 degrees Fahr. (85 degrees Cent.). The load was then suddenly thrown off, and the engine was allowed to run light for a short time with the hot jacket. A large quantity of water was then passed through the jacket, so that the temperature of the cylinder rapidly fell to 61 degrees Fahr. (16 degrees Cent.). The gas taken per suction was measured at intervals, with the results shown in Table I.

TABLE I.

Jacket temperature, outflow.	Load.	Gas, cubic feet per suction.
58° to 65° F. (14° to 18° C.)	Nil	0.1217
* 72° F. (22° C.)	Full	0.1124
114° F. (45° C.)	Full	0.1103
185° F. (85° C.)	Full	0.1072
*196° F. (91° C.)	Nil	0.1117
185° F. (85° C.)	Nil	0.1141
179° F. (81° C.)	Nil	0.1159
61° F. (16° C.)	Nil	0.1205

It will be noted that the gas consumption varies between limits differing by 12 per cent., and the indicated power would change in almost the same ratio. The change in the gas consumption at and following the points marked * is mainly due to the change of temperature of the piston, which very rapidly follows any change of load.

It will be desirable to give a statement of the meanings which will be attached in this paper to the terms "indicated power," "mechanical loss," &c.

Indicated Power is the area of the positive loop of the indicator diagram multiplied by the number of explosions per minute, and by the appropriate constant for reducing to horse-power.

Mechanical Loss is the difference between indicated power and the brake power delivered at the circumference of the fly-

wheels. It includes the negative loop of the working diagrams, and also the negative work done when the engine takes no gas.

Mean Effective Pressure is the mean pressure calculated from the positive loop of the indicator diagram. It is sometimes convenient to speak of the "mean pressure effective on the brake," and this is equal to the mean effective pressure multiplied by the mechanical efficiency.

Mechanical Efficiency is, as usual, the ratio of brake to indicated power (the latter being defined as above).

Thermal Efficiency is the ratio of indicated power to the lower calorific value of the gas used, the two quantities being, of course, reduced to the same units.

A large number of tests were made with the object of determining the mechanical losses by finding the difference between indicated power and brake power, and of comparing the result with that obtained from running the engine light under the same conditions. It will be well to describe one of these tests in detail, and to summarize the results of the others. The engine was run with a fairly full load, missing about one explosion in five cycles. The load was applied by means of rope brakes, and, as the test only lasted a short time, it was unnecessary to employ any water cooling. While careful observations were taken of the brake load (the difference between a dead-weight and a spring balance) three photographs of indicator diagrams were taken, each photograph covering about a dozen explosions. At the same time the misses occurring in about a couple of hundred cycles were counted, so that the ratio of missed ignitions to cycles was accurately known. These observations gave all the data for the mechanical efficiency, no observation of speed being necessary; the speed was, however, kept approximately constant by the governor at 180 revolutions per minute, and in what follows brake power and indicated power are both calculated on the assumption that that was in fact the speed of the engine. The following are the results of measuring the three photographs, together with the observations taken at the same time as the photographs:

TABLE II.

Jacket, exit temperature.	Explosions, cycles.	M.E.P. from diagram.	Gas per suction. Cu. ft.	I.H.P.	B.H.P.
150 deg. F. (65 deg. C.).....	0.804	100.3	0.1196	39.7	34.0
.....	0.82	99.4	0.1182	40.2	34.6
160 deg. F. (71 deg. C.).....	0.825	99.0	0.1164	40.2	34.9

The gas charge was measured, as described above, by means of a standard holder, and is correct to within 1 part in 200. It will be seen that the mean pressures from the three diagrams show very good agreement, being all within 1 per cent. of the mean value after allowing for the small change in gas charge. The mean of the three observations of brake horsepower is 34.5. The mean indicated power is 40, giving a mechanical efficiency of 86.2 per cent. The difference between brake and indicated horsepower ranges from 5.7 to 5.3 horsepower, the mean being 5.5 horsepower. In the course of the test the jacket temperature rose slightly, and, as will shortly appear, this is sufficient to account for the small diminution in mechanical losses observed in the course of the test.

Immediately after the completion of the above full-load tests the brakes were taken off and the engine run without load, the jacket water being throttled so as to prevent the engine from cooling down rapidly. Photographs were at once taken of the indicator diagram, the gas consumption was measured, and the ratio of explosions to total cycles was ascertained to be 0.141. The mean pressure was found to be 105.5 pounds per square inch, the gas consumption 0.1252 cubic feet, giving 7.35 indicated horsepower, or about 1.85 horsepower more than the difference between the indicated horsepower and the brake horsepower in the full-load tests. Had the engine in the latter case been firing every time instead of four times out of five, this difference would have been increased in the ratio $\frac{5}{4}$, becoming 2.3 horsepower.

This result—that is, that the power taken to turn the engine round at light load is rather over 2 horsepower more than the mechanical losses at full load, which was verified on many

occasions—is due almost wholly to the difference in power absorbed by the pumping strokes of the engine at light load and at full load. This difference appears in Fig. 2, which shows the suction loop in the two cases. The full line is the diagram of a cycle in which no gas is taken, the dotted line shows the negative part of a diagram of a cycle in which gas is taken. It will be seen that, as usual in these engines, the exhaust line after an explosion is considerably lower than when the engine is simply exhausting a charge of air. Moreover, when the engine takes gas, the pressure at the middle of the suction stroke is about a pound higher than when the engine is taking air only—no doubt because of the less restricted opening in the latter case. The mean pressure of the full-load suction loop is 2.9 pounds per square inch, corresponding to 1.4 horsepower at 180 revolutions; whereas in the other case the pressure is 5 pounds per square inch, giving 2.5 horsepower. In addition to this a certain amount of work is done in the compression and expansion of the charge of air which occurs when no gas is admitted, the compression line being rather higher than the expansion line. It is difficult to show the whole of this work area on a diagram, because if the spring of the indicator is sufficiently stiff to take the maximum compression pressure of 170 pounds per square inch, it is hardly sufficiently sensitive to record the small difference of pressure between the expansion and compression strokes. From a good many observations of diagrams with different strengths of spring, however, and also from calculations based on the loss of heat during compression, it would appear that the mean pressure of this part of the diagram is certainly between 1.5 pounds and 2.5 pounds per square inch. On this account, therefore, 1 horsepower must be added to the negative work done in each cycle in which no gas is taken, making approximately 3.5 horsepower at 180 revolutions per minute. This is 2.1 horsepower more than the power represented by the negative loop when the engine is firing every time, and is therefore just about sufficient to account for the difference between the full-load mechanical loss and the light-load indicated power.

An independent estimate of the power lost in pumping was made by belting the engine to the dynamo and motoring it round without allowing it to take gas. Two measurements were made, one immediately after the other; in one the engine was closed up as usual; in the other the exhaust-valve cover was removed, so that there was no pressure in the cylinder. Assuming that the belt losses and friction losses are the same in the two cases, the difference between the powers absorbed by the dynamo (after deducting dynamo losses) should be equal to the power absorbed in pumping. Two tests gave the following results, the jacket temperature in both cases being 180 degrees F. (82 degrees C.):

	Aug. 24.	Aug. 25.
Engine closed: horsepower,..	7.72	7.1
Engine opened: horsepower..	4.14	3.77
Difference	3.58	3.33

The mean is 3.45 horsepower against 3.5 horsepower estimated from indicator diagrams.

In comparing the mechanical loss with the light-load indicated power, care was taken that the conditions of the engine as regards lubrication and cylinder temperature were as nearly as possible the same. It was found that these factors make a very great difference to the engine friction, and it is important to allow for this in basing any estimate of indicated power upon the power absorbed by the engine at light load. This point is strikingly illustrated by an experiment which was made immediately after one of the tests for mechanical efficiency. At the end of that test the jacket temperature was 179 degrees F. (81 degrees C.), the engine was absorbing about 7 horsepower, exploding once in seven cycles, and the ordinary normal lubrication was going on. The gas consumption was 0.1159 cubic foot per suction. With the engine running under these conditions, and without stopping it or altering the conditions in any other way, the jacket water, which had previously been shut off, was turned fully on, so that in a few minutes the jacket temperature had fallen to 61 degrees F. (16 degrees C.). The gas consumption was then found to have risen to 0.1205

cubic foot per suction, or by about 3 per cent., and the engine was taking gas once in 4.85 cycles. Thus the power absorbed had increased, in consequence of the reduced cylinder temperature, to 10, or by about 40 per cent. on its value with the hot cylinder. A considerable quantity of water was then injected into the cylinder through the small suction valve which

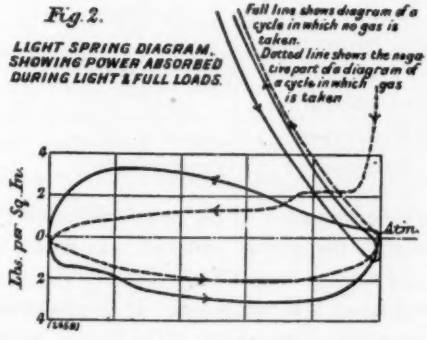


Fig. 2.
LIGHT SPRING DIAGRAM, SHOWING POWER ABSORBED DURING LIGHT & FULL LOADS.
Full line shows diagram of a cycle in which no gas is taken.
Dotted line shows the negative part of a diagram of a cycle in which gas is taken
Lbs. per Sq. In.
4
2
0
2
4
Atm.

is fitted for the purpose of preventing preignitions. The result of this was an immediate drop in the power absorbed to about 6 horsepower, or rather less than the engine was using with the hot jacket and with the normal lubrication. This very great variation in the power absorbed by the engine in friction must, of course, be within the experience of many people who have worked practically with gas engines, and it is referred to here mainly because it is so important a factor in the testing of these engines for mechanical efficiency. In the full-load test immediately preceding this experiment the brake power was 36.2, and if the indicated power had been calculated by adding to the brake power the horsepower absorbed at no load, the result might have been anywhere between 43.2 and 46.2 according as the light-load tests were done with a cold or with a hot jacket. The indicated horsepower was determined by measurement of the diagram to be in fact 41.2.

Confirmation of the great variation of power absorbed with the condition of the cylinder was obtained by motoring the engine round. The exhaust-valve cover was taken off the

engine, so that the cylinder was open to the air, and there was no loss from pumping. The power taken to drive the dynamo was measured electrically, and the dynamo losses were deducted, so that the results given below are the total frictional losses in the engine plus the loss in the belt (probably about 0.5 horsepower).

	Power Absorbed.
Engine hot (about 180 degrees F., 82 degrees C.): Normal lubrication.....	4 H.P.
Engine cold (70 degrees F., 21 degrees C.): Normal lubrication.....	6.5 H.P.
Engine cold (70 degrees F.): Excess of oil..	4.7 H.P.
Engine cold (70 degrees F.): Water injected.	2.7 H.P.

A separate determination of the power required to drive the engine round with the piston removed was made, and it was found to be 1.4 horsepower. This includes the main-bearing friction, valve-lifting, and belt losses. If this be deducted from the figures given above, the result is the piston friction, which, of course, is alone affected by the changes in cylinder temperature and lubrication. It will be seen that the piston friction varies according to conditions between 1.3 and 5.1 horsepower, the normal value with jacket at 180 degrees F. being about 2.5 horsepower.

In normal working at nearly full load (41 indicated horsepower), with the jacket at 180 degrees F., the mechanical losses in this engine may be allocated as follows:

TABLE III.

.....	Horsepower.	Per cent. of I.H.P.
Suction.....	1.4	3.4
Piston friction.....	2.5	6.1
Other friction (valve lifting, &c.).....	1.1	2.7
Total.....	5.0	12.2

The apportionment between piston friction and other friction is somewhat uncertain, as it may be to some extent affected by the existence of pressures in the cylinder, the estimate of

piston friction being based upon running the engine with the cylinder open to the air.

The effect of using water as a lubricant when the cylinder is cold is, of course, easy to understand, though the author hardly expected to find that it was so great in amount. It is not quite so marked, though still quite perceptible, when the engine is running fully loaded. In one test, in which the engine was fully loaded and the jacket water at a temperature of about 180 degrees F. (82 degrees C.) at exit, it was found that injection of water in considerable quantity diminished the number of explosions per minute by about 3 per cent. with the same brake load and speed. This difference is due entirely to the change of lubrication, the water having no effect whatever upon the indicator diagram.

TABLE IV.

Date.	Jacket temperature.	Loss. H.P.
August 16, 1906.....	150–160 degrees F. (65–71 degrees C.)	6.0
August 22, 1906.....	185 degrees F. (85 degrees C.)	5.0
August 22, 1906.....	185 degrees F. (85 degrees C.)	4.9
January 31, 1907.....	69 degrees F. (20 degrees C.)	7.1
January 31, 1907.....	150–160 degrees F. (65–71 degrees C.)	5.5
January 31, 1907.....	203 degrees F. (95 degrees C.)	4.5

The table above gives the mechanical loss in this engine observed under different conditions. The lubrication is in each case normal, and the loss is the difference between the observed brake power and the indicated power. The engine was nearly fully loaded in every case, the proportion of idle cycles varying from 0.17 to 0.20.

The results show the effect of jacket temperature. The slight reduction in loss as between the August and January experiments is to be expected, because the engine was run a good deal in the interval.

The following is a summary of the various efficiency figures relating to this engine:

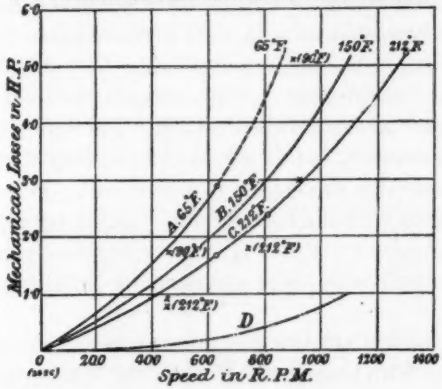
TABLE V.

Thermal efficiency	33½ per cent. to 37 per cent., according to strength of mixture.*
Mechanical efficiency for medium charge	85 per cent. to 90 per cent., according to jacket temperature.
Air-cycle efficiency	52.2 per cent.
Efficiency relative to air cycle	0.64 to 0.71.

It may be interesting in this connection to give the results of a series of tests for mechanical efficiency which were made upon a gas engine of a very different type—that is, a four-cylinder petrol motor running up to 1,200 revolutions per minute. The engine was kindly lent to the author by the manufacturers, the Daimler Company, Limited, and has cylinders 3.56 inches in diameter, with a stroke of 5.11 inches. The mechanical losses were determined by the method described by the author in a paper in "Engineering" (February 8, 1907). The method consists in running one cylinder only of the engine and of indicating that cylinder, there being no load on the engine. The indicated power of the single cylinder is then equal to the mechanical friction of the engine plus the negative work shown on the diagrams of all the four cylinders. When the engine is running fully loaded at the same speed, the loss by mechanical friction will be substantially unaltered, but the suction losses will not be quite the same, owing to the same causes that operate in the case of the large gas engine. The suction loops in the three idle cylinders are different from that in the firing cylinder, and there is, moreover, the negative work done in the compression and expansion. The pumping losses, however, in the Daimler engine bear a very much smaller proportion to the whole than in the large gas engine, owing to the relatively great size of the ports, so that no serious error is involved in neglecting the difference in these losses as between firing and not firing. Fig. 3 shows the relation between the power indicated by the single cylinder and the speed for three different temperatures. In curve A the outlet temperature

* The weaker mixtures give the higher efficiency. Full details of the tests establishing this fact will be given in a further communication.

Fig. 3. MECHANICAL EFFICIENCY OF DAIMLER ENGINE WITH VARYING TEMPERATURES OF WATER JACKET.



of the jacket water was 65 degrees F. (18 degrees C.) in curve B about 150 degrees F. (65 degrees C.), and in curve C the water was just boiling. The dotted curve D shows the power absorbed in pumping, estimated from light-spring indicator diagrams; so that the difference between this curve and any one of the others gives an approximation to the loss by mechanical friction. These curves show that the frictional losses at a temperature of 65 degrees F. are nearly double those when the jacket water is boiling. They also show that the losses increase very much more rapidly than in proportion to the speed, as is to be expected from the fact that they are due to fluid friction. These experiments were carried out for the author by Mr. L. G. E. Morse, of King's College, Cambridge.

Mr. Morse devised another method of getting the mechanical efficiency of a multi-cylinder motor, which, as it is very simple and appears to be quite accurate, is worth giving here. It consists in running the engine loaded with all the cylinders working. The load is put on by means of a Prony brake clamped to the flywheel, carrying a dead weight, which is partially supported by a spring balance having an open scale. The spring balance reads the excess of the dead weight over the brake load in the usual manner, and small changes in the brake

load may be very accurately read. In making a test one cylinder is stopped from firing by cutting off the current and the pressure on the brake blocks is reduced until the speed has come up to its old value. The reduction in brake load is then read off, and is approximately that corresponding to the indicated power of the cylinder which has been cut out. The four cylinders are treated in succession in this way, and by adding the results the indicated power of the engine is determined. Points obtained by this method with the corresponding jacket temperatures are shown by crosses (×) on Fig. 3, and it will be seen that they agree very well with those obtained by indicating only one cylinder.

The mechanical efficiency of this engine is remarkably high for its size. With boiling jacket water the mechanical efficiency is 90 per cent. at a speed of 400 revolutions per minute. It falls off to 75 per cent. at a speed of about 1,300 revolutions per minute. The thermal efficiency is also high, reaching over 26 per cent. under the most favorable conditions. The air-cycle efficiency corresponding to the compression ratio 3.85 is 41.5 per cent., so that the relative efficiency is 0.625.

Appendix I.—Description of Indicator.

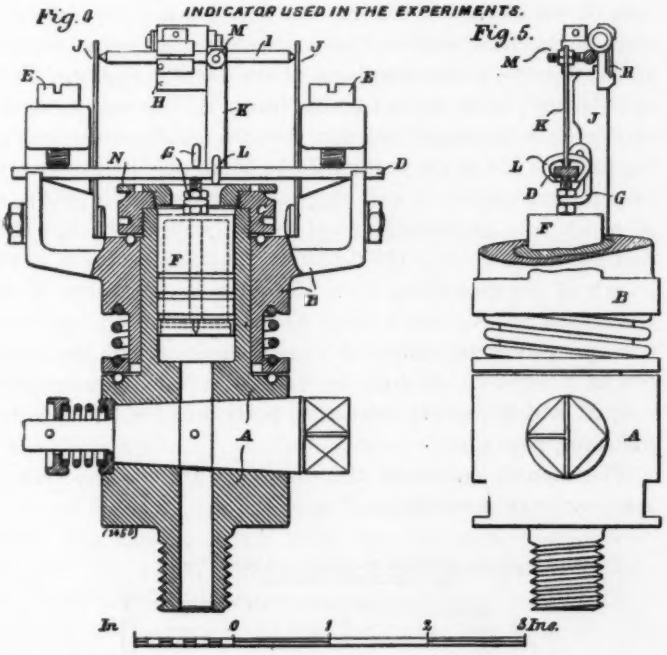
Fig. 4 is a drawing of the instrument, partly in section. The block A is screwed into the ordinary indicator hole of the engine. The frame B fits over the block, sufficient clearance being left to provide for unequal expansion. The frame is held up by a spring into engagement with the lower face of the nut C (screwed to the top of A), a ball race being interposed so as to admit of easy rotation of the frame about the axis of A.

The spring D is a piece of steel strip resting in grooves at the end of the frame B, and held by the screws E, E. This spring is slightly bowed before insertion in the frame, so that when the screws E, E are screwed home, the spring is held straight, with slight pressure on the four points of support.

The piston F slides in a bore in the block A. It is made hollow, but a plate closes its lower end. At the top it is provided with a hook G, the opening of which is slightly larger

than the thickness of the spring. The piston is thus free to move laterally, and no binding action is possible between it and the sides of the bore, such as would occur if the piston were rigidly attached to the spring.

The mirror H is clamped to a steel spindle I, the ends of which are pivoted in small holes in the vertical spring-cheeks J, J. The motion of the spring D is communicated to the



spindle and mirror by means of the piece of vertical spring K. The lower end of this piece of spring is held firmly on the face of the main spring D by means of the jaws L; the upper end is firmly clamped to the arm M which projects at right angles from the mirror spindle. (See Fig. 5, which is a section in a plane at right angles to Fig. 4.)

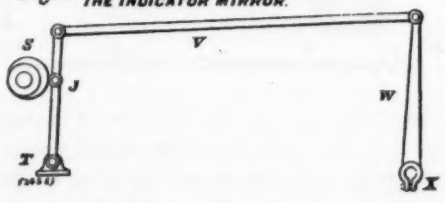
The spring K, while sufficiently rigid to transmit the motion

of the main spring to the end of the arm M without buckling, is flexible enough to allow for the angular motion of that arm. The mirror is thus turned about the axis of the spindle by an amount which is proportional to the displacement of the main spring D, and therefore to the pressure under the piston.

In order to give the other motion to the mirror the frame B is positively connected by linkage to a reciprocating part of the engine, and is thus caused to rock as a whole about the axis of the block A. The motion thus given to the frame B must be in phase with and proportional to the piston motion. In consequence of the smallness of the angular motion (about one-sixteenth of a radian) of the frame B, it is easy to secure this result with simple gearing, the effect of the curvature of the paths of the joints in the linkage being negligible. A convenient arrangement is that shown diagrammatically in Fig 6, in which S is an eccentric fixed to the crank shaft, and such that the diameter is to the throw as the crank radius is to the length of the connecting rod. The lever W is jointed at one end to the rod V, which takes its motion from one end of a lever pivoted at the other end T, and engaging with the eccentric by a roller J. At the other end, W is fixed to a clamping ring X, which fits over the turned portion of the frame of the indicator, Fig. 4.

The manner in which the diagrams are made visible is apparent from the diagram, Fig. 7.

Fig. 6. DIAGRAM OF LEVERS FOR OPERATING THE INDICATOR MIRROR.



The source of light is a fine hole P illuminated by an ordinary four-volt incandescent lamp. The rays from this, after reflection from the plane mirror of the indicator Q, fall upon the

convex lens R_1, which is placed about 18 inches from the mirror, and is 4 inches in diameter. The focal length of this lens is about equal to its distance from the mirror, and the beam of reflected light is therefore refracted to a direction about parallel with the axis of the lens. The beam comes to a focus in the plane R_2, and traces out in that plane the indicator diagram of the engine, the vertical displacements of the spot (corresponding to the tilting of the mirror about the spindle) being proportional to the pressure, and the horizontal displacements (corresponding to the rocking of the indicator frame) to the piston motion. With a sufficiently powerful source of light this diagram could be made visible by a ground-glass screen placed in the plane R_2; but in order to render it visible with a

Fig. 7.

small lamp, a transparent screen is used and a second lens R_3 is interposed about 10 inches from R_2. This lens is of equal diameter with R_1, and refracts the beam of light (which before striking it is parallel to the axis) to its principal focus R_4, where the eye is placed. The beam is at the same time converted into a parallel beam, and the spot is seen sharply defined on the screen. The diagram traced by the spot is seen as a bright line of light. The screen is engraved with horizontal and vertical lines, on which the diagram is projected. The pressure at any point can thus be easily read off, or the diagram can be plotted down on squared paper.

Three pistons are used, the areas being in the ratio of 1, 2 and 4. There are two springs, which are ground so that the stiffness are in the ratio of 1 to 5. A wide range of sensibility is thus obtained. The smaller pistons fit inside liners which are inserted in the bore of the block A, Fig. 4. The spring is very easily changed by slacking the screws EE and slipping the springs out together with the spindle and mirror, the spring

cheeks JJ being slightly separated to allow of the spindle being taken out. When the spring has been removed, the piston can also be readily taken out by removing the cap N, Fig. 4, which serves also as a stop to prevent excessive bending of the spring.

The indicator is very easily calibrated by dead weights. The calibration is found to remain constant within 1 or 2 per cent. when the spring is removed and replaced. Suction pressures are registered on the same scale as those above atmosphere, on account of the slight initial set in the spring.

Appendix II.—Conditions Determining the Gas and Air Taken per Suction.

The total quantity of mixture drawn into the engine per suction is determined mainly by the temperature of the cylinder walls and piston, and is not affected much by the temperature of the gas left in the compression space from the previous stroke. This is most easily seen by supposing the incoming charge to be kept adiabatically separate from the residual gas. The total charge then drawn in will obviously be independent of the temperature of that gas. If, now, at the end of the suction stroke, when all valves are closed, the incoming charge and the residual gas are mixed, the pressure will not change. For the internal energy of a given volume of gas having constant specific heat is a function of its pressure, and is independent of its temperature or of the distribution of temperature in it. It can make little difference whether the mixing takes place at the end of the stroke, as supposed, or during the stroke, as, in fact, it does. In either case the quantity of gas drawn in is nearly independent of the temperature of that with which it mixes. The author believes that this was first pointed out by Mr. Dugald Clerk, in the Appendix to his paper on "The Limits of Thermal Efficiency in Internal-Combustion Engines."

It follows that in an engine governing by hit-and-miss, the amount of gas and air drawn in will be substantially the same after a miss as after an explosion. The ratio of gas to air in the charge taken in, and the quantity of gas, will also be much the same, provided that the opening of the gas cock and the

pressure outside be the same. Since, however, the incoming charge mixes with cold air instead of hot products, the weight of the total charge present in the cylinder at the end of suction will be greater, its temperature will be lower, and the percentage of gas present in it will be less. The diagram should therefore be unaffected except in so far as the weakening of the mixture improves the efficiency, and so enlarges the area. This should cause an enlargement of from 4 to 5 per cent., or considerably more than has usually been observed in the engine used for the tests described in this paper. The inference is that the gas supply is, in fact, rather less after a miss than after an explosion.

Fuller investigation of the matter shows that this must be so. Let

v = quantity of gas left in compression space;
t = temperature of gas left in compression space;
V = quantity of gas and air taken in;
T_1 = temperature of gas and air taken in before entering.
v_0 = volume of cylinder contents at completion of suction;
t_0 = temperature of cylinder contents at completion of suction;

the quantities of gas being expressed in standard cubic feet,* and the temperature on the absolute Centigrade scale.

Then at the commencement of suction we have V standard cubic feet of air and gas outside the engine at temperature T, and v inside at temperature t, all at atmospheric pressure p_0. Thus the stuff which is ultimately to form the total charge has at this point the energy $k\ (V\ T + v\ t)$, where k is the thermal capacity at constant volume, or 19 foot-pounds.

When suction is finished the stuff is all inside the engine, and it then has the energy $k\ (V + v\ )\ t_0$.

During suction work is done by the engine to an amount W, which can be calculated from the light-spring diagram. Some heat H is also received from the cylinder walls. Some of this

* That is, cubic feet reckoned under the standard pressure of 760 millimeters of mercury (14.7 pounds per square inch) and the standard temperature of 0 degrees C.

work goes to increasing the internal energy, and some is done against the atmospheric pressure. The latter item is equal to the pressure multiplied by the increase of volume of the stuff —that is, to

$$\left\{ \frac{V(t_o - T)}{273} + \frac{v(t_o - t)}{273} \right\} p_o,$$

p_0 being the atmospheric pressure in pounds per square foot.

Equating the net work done on the stuff plus the gain of heat to the increase of energy, we get

$$W - \left\{ \frac{V(t_o - T)}{273} + \frac{v(t_o - t)}{273} \right\} p_o + H = k(V + v)t_o - k(VT + vt).$$

Or, since $k + \frac{p_o}{273} = k_p$, the specific heat at constant pressure:

$$W + H = k_p \left\{ V(t_o - T) + v(t_o - t) \right\}.$$

Now,

$$\frac{(V + v)t_o}{273} = v_o;$$

whence, substituting for t_o,

$$VT = -\frac{W + H}{k_p} + 273\, v_o - vt.$$

If V' be the actual volume (before entering) of the gas and air taken in, so that $V' = \frac{T}{273} V$, and if v_s be the stroke volume $\left(= v_o - \frac{tv}{273}\right)$, the last equation may be written:

$$V' = v_s - \frac{W + H}{k_p \times 273},$$

or the actual volume taken is less than the stroke volume by the quantity $\frac{W + H}{k_p \times 273}$.

The hotter the contents of the compression space, the less heat will be taken in from the cylinder walls during suction. The charge taken in after an explosion will therefore exceed that taken in after a scavenging stroke, the cylinder and piston temperatures being the same.

It is assumed in this calculation that the pressure is atmospheric at the beginning and end of the suction stroke. With good valve action this is sufficiently nearly the case; and when it is not so it is easy to make the necessary correction. A further assumption is that the whole entering charge comes in from the air and gas pipes. This is not quite true, since in most engines the exhaust valve remains open for some time after the suction stroke has begun, and some stuff may back in from the exhaust pipe.

In the engine on which these experiments were made the mean pressure in the suction stroke when taking both gas and air is 2 pounds per square inch. Thus,

$$\frac{W}{t_p \times 273} \text{ is } \frac{2 \times 144 \times v_s}{26.75 \times 273} = 0.04\ v_s$$

The volume drawn in is therefore reduced to 4 per cent. below the stroke volume on account of the work done on the charge in drawing it in. The substantial correctness of this result has been verified by actual measurement of the cylinder contents at the beginning and end of the suction stroke, the engine being motored round and sucking air only, so that there was but little exchange of heat between the gas and the cylinder walls. The temperature of the charge at each end of the suction stroke was measured by a platinum thermometer.*

The value of H cannot, of course, be calculated, but it is not difficult to measure the actual volume of air taken by means of an anemometer. Tests of this kind under various conditions were made on the Crossley engine, of which the following are the most important. In each case λ is the ratio of the

* "On the Measurement of Gas-Engine Temperatures," "Philosophical Magazine," January, 1907.

total volume of gas and air taken in per suction (V^1) to the stroke volume (v_s). The stroke volume is 1.26 cubic feet:

1. Engine motored round without firing, gas-cock shut, $\lambda = 0.87$.

2. Engine motored round without firing, gas-cock open, $\lambda = 0.90$.

3. Engine firing 80 per 100 cycles. Jacket 62 degrees to 69 degrees F. (16 degrees to 20 degrees C.), $\lambda = 0.87$.

4. Engine firing 87 per 100 cycles. Jacket 173 degrees to 200 degrees F. (78 degrees to 93 degrees C.), $\lambda = 0.825$.

In No. 2 H cannot have amounted to much, as the jacket and piston were both cold. About half of the 10 per cent. loss of volume is to be ascribed to the work done (W) as already explained, the other half is due to gas coming in from the exhaust pipe during the first portion of the suction stroke. In No. 3 the piston was hot because of the continual firing; it would have a temperature of at least 350 degrees C. (662 degrees F.). Thus H is considerable, and the result is seen in a reduced charge as compared with (2). In (4) H is further increased, and the charge is further reduced, by the hot jacket. It was found in these tests that the ratio of gas to air taken in varied somewhat, though the opening of the gas valve and the gas pressure were always the same. The range of variation amounted to about 5 per cent. on the ratio, and it could not be correlated definitely with any change in conditions. It takes place slowly, however, and does not affect the conclusion stated above as to the effect of a missed ignition on the charge of gas taken. It is probably due to changes in the temperature distribution in the engine, which would alter the relative amount by which the gas and air streams are warmed in coming in.

The anemometer was calibrated by motoring the engine round, the setting of the exhaust valve being altered, so that it opened at the out-center and closed a little before the in-center. The overlap of the exhaust and inlet-valves was thus reduced to about 7 degrees only, and the error due to air coming in from the exhaust pipe was practically eliminated.

Measurements of temperature (by platinum thermometer) and of pressure were made at the opening and closing of the inlet valve, and the cylinder contents at these points were thus determined. The calibration so made was accurate within 2 or 3 per cent. A somewhat similar method was used by the Institution of Civil Engineers' Committee; but they did not make any measurement of temperature. On this account their calibration was probably somewhat too high; perhaps as much as 5 per cent. For their purpose this was near enough, since they only required the total volume of air passed through the engine for the purpose of estimating the amount of a small correction in their heat quantities.

Appendix III.—On the Loss of Heat in Compression.

In this engine the pressure reached at the end of the compression stroke, when compressing air only, is 173 pounds per square inch absolute, with a normal barometer. The pressure at the closing of the inlet valve under the same circumstances is 0.15 pound per square inch above atmosphere, or 14.85 pounds per square inch absolute. The ratio in which the volume is reduced between the closing of the inlet valve and the completion of compression is 6.17. Assuming that there is no leakage, it follows that the absolute temperature is increased by the compression in the ratio $\frac{173}{1485 \times 6.17}$, or 1.89. The rise of temperature is therefore $0.89\,\theta_0$ where θ_0 is the temperature at the beginning of compression. Assuming that the compression curve is of the form pv^n = constant, the index n has the value of 1.35. As a matter of fact, n is less at the beginning of compression than at the end. The work done in compressing air according to the law $pv^{1.35}$ = constant, so that the volume changes in the ratio 6.17 would be sufficient (if there were no loss of heat) to raise its temperature in the ratio 2.14. This is most easily seen by noting that the curve $pv^{1.35}$ = constant is the adiabatic compression curve of a gas whose specific heat is $\frac{7.75}{0.35}$ = 22.2 foot-pounds per standard

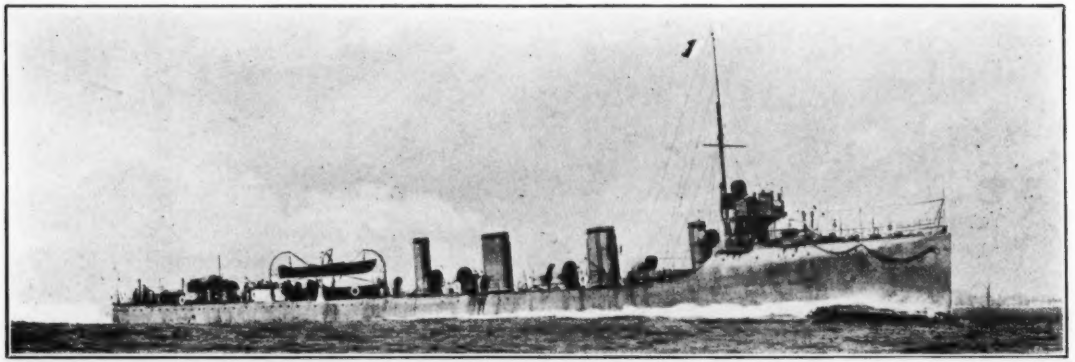
cubic foot. The temperature rise corresponding to compression in the ratio 6.17 is, as already seen, $0.89\theta_0$; and this is the rise of temperature produced in a gas of specific heat 22.2 by the work under the compression curve. The same amount of work, applied to heating air, would therefore raise its temperature by $\frac{22.2}{19} \times 0.89 = 1.04$ times θ since the specific heat of air is 19 foot-pounds. Since the actual rise of temperature of the air is $0.89\theta_0$, it follows that the heat lost in compression is such as would raise the temperature of the air by $1.04 - 0.85 = 0.15$ times θ_0. Thus about 14 per cent. of the work done in compression in this engine is lost to the cylinder walls. This result depends on the assumption that the compression curve has the form $pv^n = \text{constant}$; but the result will not be greatly different if n varies somewhat during the compression stroke, provided that the pressure and volume at the beginning and end of compression are the same.

The mean absolute pressure of the compression curve (still assumed to be $pv^{1.35} = \text{constant}$) is 3.03 times the initial pressure, or 45 pounds per square inch.

We have now to consider the expansion curve. If the expansion be assumed to be adiabatic, the pressure after expanding 6.17 times will be $\frac{173}{(6.17)^{1.41}}$ or 13.5 pounds per square inch. This is not far from the value actually observed by the indicator, and it is probable that very little heat is lost in the expansion. The mean pressure under the assumed adiabatic expansion curve is starting at 173 pounds per square inch and finishing at 13.5 pounds, just over 43 pounds per square inch. The mean pressure in the loop formed by the compression and expansion curves is therefore about 2 pounds per square inch.

H. M. S. *MOHAWK*.

The ocean-going torpedo-boat destroyer *Mohawk*, built by Messrs. J. Samuel White & Company, Ltd., of East Cowes, I. W., for the British Navy, ran an official trial on the Maplin



THE BRITISH TORPEDO-BOAT DESTROYER "MOHAWK."

Mile on Tuesday, November 5, obtaining a mean speed of 34.3 knots per hour. This is 1.3 knots in excess of the contract speed of 33 knots, which speed, considering the high basis speed, is a remarkable result, the oil-fuel consumption being very satisfactory.

The principal dimensions, etc., of the ship are: Length, 270 feet; displacement, 800 tons; armament, three 12-pdr. Q.F. guns, two 18-inch revolving torpedo tubes; speed to be maintained on a six-hours' full-power trial, 33 knots; radius of action at economical speed, 1,500 nautical miles.

The vessel is propelled by turbine machinery, comprising five turbines (three ahead and two astern), driving three shafts and propellers, built by Messrs. J. S. White & Co., Ltd., under license from the Parsons Marine Steam Turbine Co., Ltd., the machinery being of about 14,500 I.H.P.

Steam is supplied by six water-tube boilers, each of about 2,400 H.P., of the "White-Forster" type, made by the same firm, these boilers being fired by liquid fuel on a system which has been experimented with successfully by the Admiralty for some years.

No cold storage is provided in the vessel, as she will rely entirely on the liquid-fuel installation.—"Page's Weekly."

THE SPEED OF TORPEDO-BOAT DESTROYERS.

The trials which have recently been carried out in the torpedo-boat destroyers of the *Tribal* class have been remarkable for the ease with which the contract speed has been obtained, in spite of the limitations imposed. It will be remembered that a speed of 33 knots was to be maintained over a period of six hours, while the amount of fuel burned per square foot of heating surface per hour was limited; the fuel was oil, which these vessels are designed alone to carry. They were also required to have a radius of action of not less than 1,500 nautical miles at 13 knots. That these requirements, which in some respects are conflicting, have been carried out, and the contract speed exceeded in all the boats

of the class yet tried is a vindication, if such were necessary, of the value of oil as fuel in vessels designed for purely military purposes.

The limitation of the amount of oil burned per square foot of heating surface is, no doubt, wise, in view of the danger of local overheating, which is always a possibility when such fuel is used. The usual allowance of heating surface per indicated horsepower in water-tube boilers of the "Express" type, when used in conjunction with reciprocating engines, is $2\frac{1}{8}$ square feet, which means that at full power the average evaporation over the whole of the heating surface is about 8 pounds per square foot. As the evaporation is very unequally divided among the tubes, those nearest the fire accounting for a much larger part of the steam generated than those more remote, an average of 8 pounds is probably quite high enough, if the fire rows are not to be unduly stressed. When burning oil fuel there is a greater possible disparity between the work done by the fire rows and the remainder of the tubes than in the case of a coal-fired boiler. The maximum temperature of the oil jets is attained in a zone of comparatively small area a foot or so from the burner nozzle, and the boiler tubes in that vicinity effect a larger proportion of the evaporation than would be the case if the furnace temperature were more equally distributed. It may be assumed that the quantity of oil fixed as a maximum to be burned per square foot of heating surface is the result of the Admiralty experiments on the evaporative results to be expected per pound of oil in boilers of this type, and the mean evaporation per square foot of heating surface which it has been found advisable not to exceed. Such a limitation necessitates ample heating surface in order to make sure of the power required for the contract speed; but, on the other hand, every square foot added means extra boiler weight and extra displacement, and some reduction in the radius of action. Fortunately, it appears that there was ample margin in this respect, though it seems from the speeds obtained—in one case 2.36 knots above the contract—that the designers have erred on the safe

side as regards heating surface. These results, it may safely be assumed, are unattainable in similar vessels fired with coal, for, although the ill-fated destroyers *Viper* and *Cobra* reached equal speeds to those now realized in the *Tribal* class, they were not at their sea-going displacement, and had no limitations as to the amount of fuel to be burned. We believe, moreover, we are right in saying that the *Viper*, in the course of her short career on service, never approached her measured-mile performance. How much of the success is due to the turbines it is difficult to say. Possibly the equipment of such a vessel with reciprocating machinery of, say, 15,000 indicated horsepower on two, or even three, shafts would present insuperable difficulties within the limits of space and weight allowable, and taking also into consideration the straining actions due to the reciprocating forces on a comparatively light hull. Whether this mechanical problem is capable of solution or not, the superiority of oil fuel for the purpose of maintaining speed over a considerable period is abundantly demonstrated.

Two factors operate in the maintenance of speed when burning coal, the necessity of cleaning fires and the endurance of the stoker, neither of which has any significance when burning oil fuel. When burning coal at the rate of combustion required in these small-tube boilers for full speed, one or other of the furnace doors is practically always open for stoking, and the volume of cold air admitted must detract both from the efficiency of the boiler and its steam-giving capacity. An indifferent stoker, by keeping each furnace door open a few seconds more than necessary may, in the sum total of all the openings, make just the difference between a satisfactory and an unsuccessful trial. Oil burning still requires skill and intelligence on the part of the stoker, and perhaps of a higher order, but it does not entail that hard manual labor and constant supervision which makes a full-speed trial on a torpedo-boat destroyer burning coal more like a nightmare than an engineering performance. In one particular especially, the regulation of the boiler feed, the su-

periority of the oil-fired boiler is marked. Automatic feed regulators have not been a pronounced success in water-tube boilers of the small-tube type, and it is always necessary to supplement the working of the apparatus by manipulation of the feed-check valve, the amount of hand regulation depending upon the character of the stoking and the consequent steadiness or otherwise of the rate of evaporation. With oil fuel, once the burners are set the feed pumps can be adjusted to the evaporation with a reasonable certainty that no manipulation of the feed valve will be required. In a word, stability of working conditions on which maintenance of full speed depends is easy of attainment with oil fuel, while it is comparatively difficult, even with expert stoking, when burning coal.

The speeds obtained in the *Tribal* class, though remarkable, do not appear from the particulars available to be due to any increase in the propulsive coefficient; they are simply the logical result of being able by means of oil-fired boilers and turbine engines to maintain a high power which otherwise would not be within reach. It is not intended to minimize the importance of the results; they are a fitting culmination—if that point has yet been reached—of the experiments which have been carried out by the Admiralty at Portsmouth and elsewhere, on the use of oil fuel in naval boilers; and the success is all the more gratifying when it is remembered that several other Admiralties, after a study of the subject, have practically given up the quest. But while it is permissible that we should shake hands with ourselves on the results, two considerations should moderate our enthusiasm. The first is that we are still dependent upon foreign countries for our supplies of oil fuel, and the other is that these turbine-engined boats are admittedly still a long way behind those with reciprocating engines in fuel economy at cruising speeds. The first-class torpedo boats recently added to the Navy List—formerly called "Coastal Destroyers"—are able at 13 knots to steam about 36 nautical miles per ton of fuel oil consumed. This is just about the same as the earlier

30-knot destroyers, with reciprocating engines, burning coal. The torpedo boats are only about two-thirds the displacement of the destroyers, and it must be remembered that the former are using a fuel of 30 per cent. greater calorific value than the latter. It is true that on account of the difference in length 13 knots is a higher relative speed in the torpedo boat than in the destroyer; but, making every allowance for this, there is obviously a very considerable margin in economy at this speed in favor of the reciprocating engine. The radius of action of the torpedo boats referred to is only about 800 miles at 13 knots, that of the *Tribal* class of destroyers about 1,500 miles, while the earlier 30-knot destroyers burning coal had a radius of action of nearly 3,000 miles.

It is difficult to assign the relative importance of speed and radius of action. Speed is an offensive quality, but the necessity for its use may not arise till after many days' steaming at ordinary speed, and radius of action is, therefore, also an offensive quality. The two together are the modern equivalent of the weather gauge of Nelson's day, as the vessel having superiority in these respects can always choose to give or to decline battle. From the nature of our position it has always been necessary, and probably always will be necessary, for us to hold this advantage over our rivals. In "Before Port Arthur in a Destroyer," supposed to have been written by a Japanese naval officer in command of one of these vessels, there is much internal evidence of the value of radius of action. We read of the boats engaged in patrolling before Port Arthur coaling from a cruiser every twelve hours, and frequent mention of returning to a base to coal after only a few days at sea. In the battle of Tsushima the Japanese destroyers do not appear to have been in evidence till near the end, when they attacked the almost completely disabled Russian ships. Speed then was not of great importance, as the Russian ships could neither fight nor run away, but if the destroyers had been a day or two at sea they might not have had sufficient coal to deliver an attack at full speed had they desired to do so. Conditions such as these may operate in

any conflict in which our destroyers may be engaged, with the added disadvantage of increased distance from a base. Floating bases from which supplies of fuel may be obtained are, of course, a factor to be considered, but such vessels are necessarily slow in speed and require convoying, and they may, under certain conditions, hamper a fleet as much as help it. In the *Tribal* class, by sacrificing a knot in speed and putting the weight saved in machinery into fuel, the radius of action would be increased by about 300 miles. As we are now possessed of destroyers which in the matter of speed are much in advance of anything possessed by any other naval power it is worth considering whether sufficient attention has not, for the present, been paid to this quality, and whether more attention should not now be paid to increasing the radius of action by increase of fuel supply and improvement of economy of the propelling apparatus at the cruising speed.—"The Engineer."

H. M. S. *TARTAR.*

The official six-hours' full-speed trial of H. M. S. *Tartar*, one of the larger class of ocean-going destroyers recently built for the British Admiralty by Messrs. John I. Thornycroft & Co., Limited, Southampton, was satisfactorily carried out at the mouth of the Thames on Monday, December 16.

The speed obtained on the six runs over the measured mile was 35.672 knots, with mean revolutions of 775.5 per minute; while the mean speed obtained during the six hours was 35.-363 knots, with mean revoluions 768.8 per minute. The highest speed attained on the measured course was 37.037 knots with the tide. The contract speed required by the Admiralty was 33 knots, so that it will be seen that this has been exceeded by 2.363 knots by the *Tartar*.

The table herewith gives the results obtained throughout the trial.

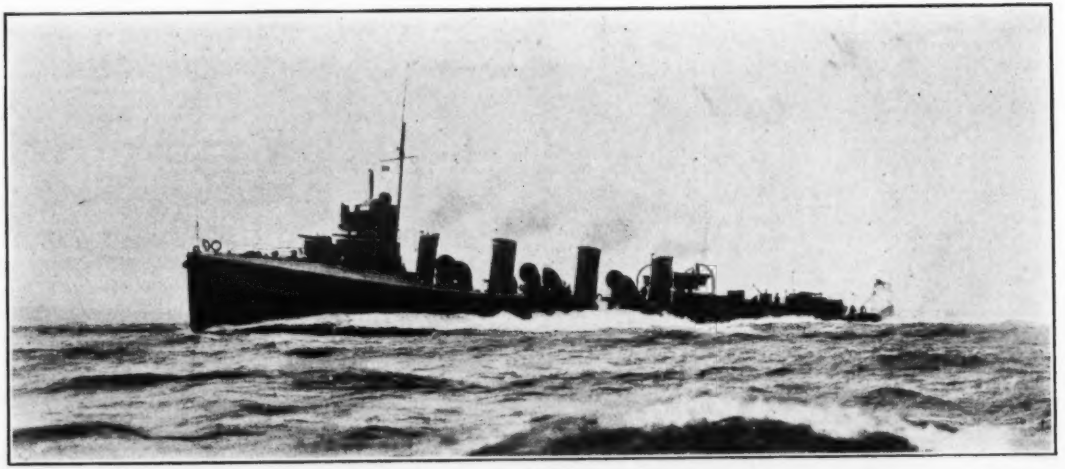


Fig. 1.—THE "TARTAR" STEAMING AT 34¼ KNOTS.

Number.	Speed on six runs, in knots.	Mean speed during each hour.	Mean revolutions per minute on six hours.
1	36.810	35.137	763.9
2	34.549	35.245	766.2
3	36.961	35.401	767.9
4	34.286	35.301	767.44
5	37.037	35.429	770.2
6	34.286	35.665	775.4
Admiralty mean.	35.672	35.363	768.8

The following Admiralty officials were present: Engineer-Commander W. S. Frowd, Engineer-Commander L. J. Stephens, Engineer-Lieutenant E. J. Rosevere, Engineer-Lieutenant Rundle, and Constructors G. H. Ball, R. J. Grimshaw and H. G. White, Admiralty Overseer, and F. E. Hoe, Assistant Overseer; the firm of Messrs. Thornycroft being represented by the general manager, Mr. Callaway, and the technical directors, Messrs. S. W. Barnaby and T. Donaldson.

The splendid result achieved has been due to the employment of the latest advances in scientific marine engineering practice, together with the skill and special experience gained by the builders during the many years in which they have been engaged in building high-speed vessels.

The *Tartar*, which we illustrate in Fig. 1, is a vessel 270 feet long and 26 feet beam. She is built principally of high-tensile steel, and the methods adopted of constructing the hull are such as to obtain the maximum of strength for the least amount of material.

The propelling machinery (which was made by Messrs. Thornycroft & Co. at their Southampton works) is of the Parsons steam-turbine type.

The fuel used is a heavy oil, which is injected into the furnace by means of special burners of Admiralty pattern, and the boilers, one of which is shown in Figs. 2 and 3, are of the

Fig. 2.

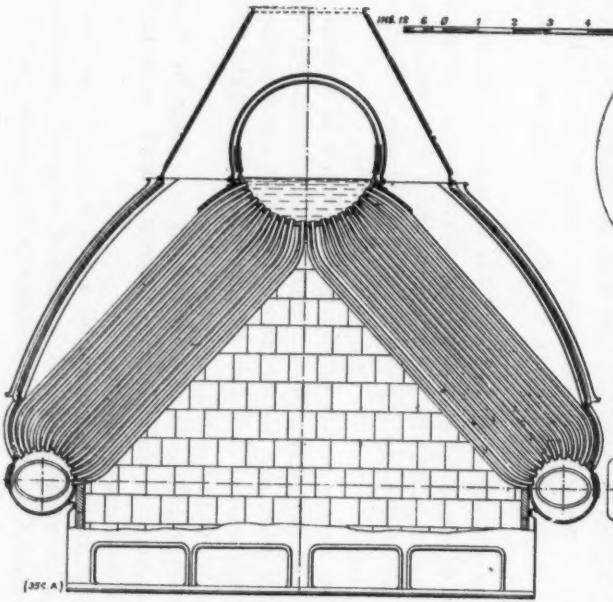
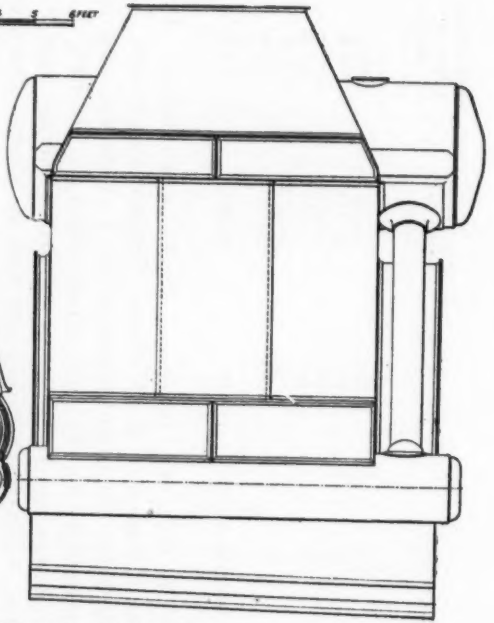


Fig. 3.



BOILERS OF H. M. TORPEDO-BOAT DESTROYER "TARTAR."

Thornycroft water-tube type (six in number). This combination provides a steady and ample supply of steam, the working pressure being 220 pounds per square inch.

As will be seen from the illustrations, the tubes are straight except at the ends where they enter the steam barrel and water barrels. It will be observed that the design lends itself well to the protection of the upper barrel from the fierce heat of the oil-fuel furnace. Each boiler has 5,300 square feet of tube surface; the fire-box tubes are $1\frac{3}{8}$ inches in diameter and 10 L. S. G. thick, and the remainder are $1\frac{1}{8}$ inches in diameter and 12 L. S. G. thick.

The advantages gained by using oil fuel are very apparent, as will be observed from the illustration (Fig. 1) taken from a photograph of the *Tartar* when running at $34\frac{1}{2}$ knots in Stokes Bay, using oil fuel. It will be seen that from the funnels there is hardly a trace of smoke, which is due to the precision with which the necessary amount of air can be adjusted for perfect combustion. Another important matter is the freedom from the continual shower of small ashes from the funnels falling upon the deck, so usual in coal-burning ships, and the total absence of flaming at the funnels. Again, the ease with which the speed may be reduced almost instantly is a very important consideration.

The vessel will be fitted with wireless-telegraph apparatus. Mechanical means are provided for ventilating the engine room when the hatches are closed in bad weather. The usual system of voice pipes is replaced by an installation of loud-speaking telephones, fitted at all the important stations throughout the ship. The main deck is not obstructed by high coamings along the boiler rooms—an advantage due to the use of the Thornycroft type of boiler—and thus allows of easy passage from side to side.

The following is a list of a few of the torpedo boats and destroyers built by Messrs. John I. Thornycroft & Co., Limited, each of which created a record in its day:

Name.	Government.	Date.	Speed, in knots.	Type.
Ariete.....	Spanish	1887	26.003	Torpedo boat
Daring.....	English	1893	28.213	Destroyer
Boxer.....	ditto	1894	29.170	ditto
Desperate.....	ditto	1895	30.350	ditto
Albatross.....	ditto	1898	31.500	ditto

The total number of torpedo boats and destroyers built by this firm is 293, and the *Tartar* is the first one built and completed at the Woolston Works, where at the present time there are building the *Amazon*, which is a little larger than the *Tartar*, and four torpedo boats fitted with oil-fuel arrangements and the Parsons type of steam turbine, for the British Admiralty. Since the trial of the *Tartar* an order for a second *Amazon* has been received by the firm.—"Engineering."

NEW TURBINE STEAMERS FOR THE MEDITERRANEAN.

January 18, saw the departure from the Clyde, after a most successful series of trials, of the new turbine steamer *Cairo*, built along with the sister ship *Heliopolis*, by the Fairfield Shipbuilding and Engineering Company, Ltd., for the Egyptian Mail Steamship Company's express service between Marseilles and Alexandria. The trials of both vessels, which were carried out at load draught during the stormy days of November and January, resulted in the attainment and continuance of a speed of over 20½ knots, which is exceptionally high for vessels of their dimensions and passenger capacity. During the trip from the Clyde to Plymouth, the *Heliopolis*, in the Irish Sea, kept up the remarkable speed of 21.9 knots for a period of three hours, and had to be slowed down to avoid arriving too early at Plymouth, where arrangements had been made for her reception. From Plymouth to Marseilles she again showed her qualities as a racer, covering the distance in the record time of 95½ hours, while on her first voyage the distance from Marseilles to Alexandria was covered in 72½ hours, and on the return trip she gave clear indica-

tions that, barring unfavorable weather conditions, she can still further reduce the time between these points.

Passengers on the *Heliopolis* report the behavior of the vessel to be all that could be desired. The absence of vibration in any part of the vessel is notable, and bears testimony to the care and skill shown by the builders in the balancing and arranging of her machinery and propellers and in the stiffening and pillaring of her structure. The ease of her pitching motion when the wind and sea were ahead, and of her rolling with a beam sea, made it difficult to believe that one was really at sea at all, when in a cozy deck stateroom. Even when facing a gale of such violence that it was considered advisable to slow down to 10 knots to prevent danger of carrying away any of the forward-deck gear, the passengers were able to dine in comfort without having recourse to "fiddles," and with no risk of wine spilling.

The *Heliopolis* and the *Cairo* have a period of roll of about 20 seconds, which is remarkably and unusually long for vessels of their dimensions; and this fact together with the general excellence of their arrangements, make the voyage seem all too short for the full enjoyment of the many pleasures afforded. The dimensions of these two vessels, upon the possession of which the Egyptian Mail Steamship Company, Limited, are to be congratulated, are as follows: Length over all, 545 feet; breadth, 60 feet 3 inches; depth from keel to shelter deck, 38 feet; tonnage, 12,000 tons gross; horsepower, 18,000; mean speed on 12-hours' trial, 20.6 knots.

The hull is subdivided into ten compartments by transverse bulkheads, with cellular double bottom right fore and aft. There are seven decks—boat, promenade, bridge, shelter, upper and main decks.

Extensive stateroom accommodation is provided for a large passenger list, and this and the public rooms are, alike in dimensions and decoration, close imitations of the best practice in Atlantic steamship building. The first-class passenger public rooms include a café on the boat deck, a music room

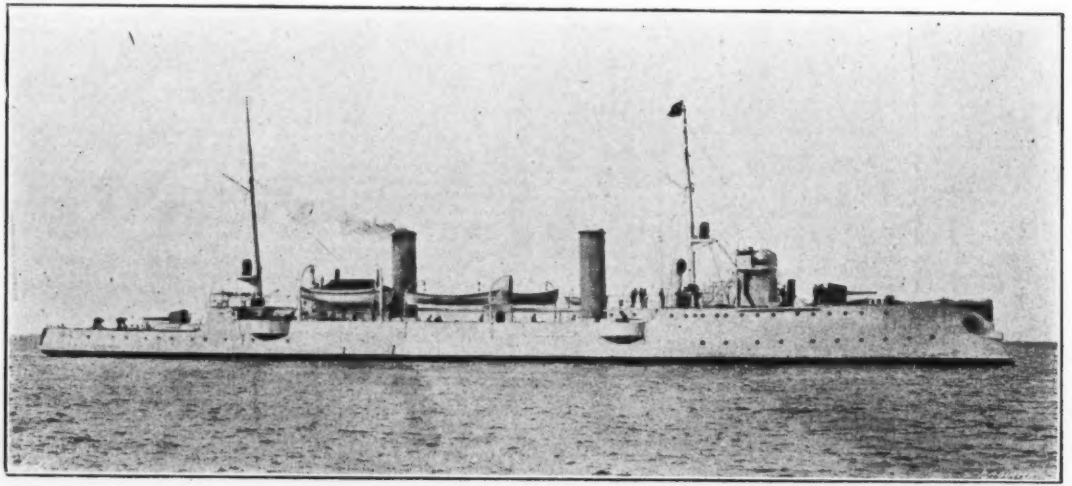
on the promenade deck, a library and smoking room on the bridge deck, and dining saloon on the shelter deck. The second-class public rooms include a smoking room, social hall and dining saloon on the shelter deck. A prominent feature is the extensive promenade space provided on the three decks above the molded dimensions of the ship. Ventilation, too, had special consideration.

The machinery is of the Parsons type, driving three screws. The center propeller is operated by the high-pressure turbine, and the two wing propellers by the low-pressure turbines, the astern turbines being fitted also to the wing shafts. Full power is developed when the engines are making 340 revolutions.

A series of progressive-speed trials was made by each ship. For 200 revolutions the speed was 12.198 knots; for 261 revolutions, 15.419 knots; for 314 revolutions, 18.16 knots; for 346 revolutions, 19.83 knots; and for 372 revolutions, 20.75 knots. Following upon this trial the vessels, at full draught, had to be run for twelve hours at full speed. The *Heliopolis*, with a draught of 21 feet 5½ inches, made 20.53 knots for 366.3 revolutions, while the *Cairo*, with a draught of 22 feet, made 20.6 knots for 372.5 revolutions. But when we publish our detailed article on the ships we shall be able to deal with these trials in greater detail.—"Engineering."

NEW TORPEDO CRUISERS FOR TURKEY.

The illustration given herewith shows one of the two new Turkish gunboats, the *Peit-i-Shevket* ("His Majesty's Messenger") and the *Berc-i-Satvet* ("The Lightning of Force"), which were laid down at the end of 1906 and delivered in the month of October last, after a series of satisfactory trials. The *Peit-i-Shevket* and her sister ship, which were built by Fried. Krupp, A. G. Germaniawerft, Kiel, are now on their way from this harbor to Constantinople. On general lines they embody an improved design of the old tor-



TURKISH TORPEDO-BOAT CRUISER "PEIT-I-SHEVKET."

pedo gunboats *Pelenk-i-Deria* and *Namet.* Their principal dimensions are: Length, 262 feet; breadth, 27 feet 6¾ inches; draught, 8 feet 2¾ inches. Their displacement in normal load condition is about 740 tons, their coal supply 240 tons. At speed trials they attained one knot more than the contracted 22 knots. They are armed with two 10.5-cm. (4-inch), six 5.7-cm. (2¼-inch), two 3.7-cm. (1½-inch) guns, all Krupps, and five Hotchkiss quick-firing guns. Torpedo armament: One bow tube and two deck tubes, one on each broadside, all for 18-inch torpedoes.—"Engineer."

THE ITALIAN BATTLESHIP *REGINA ELENA.*

The designer of this class is Colonel Cuniberti, of the Corps of Italian Naval Constructors, who was probably the first to put forward the idea of a very fast and heavily-armored battleship provided with a uniform 12-inch armament. A very casual inspection of the *Regina Elena* is sufficient to convince anyone that Colonel Cuniberti's genius does not stop at imaginary *Dreadnoughts.* The ship is only of 12,625 tons displacement, but in the very fact of this small displacement lies the marvel. She is quite the last word in economy of weights and utilization of space. Nor does she stop there. Under the big-gun turrets a novel girder construction is introduced to take up the stress of firing, and the success of this may be gauged from the fact that all possible guns have been fired ahead, astern and on the broadside without the slightest inconvenience to the vessel.

The armament is as follows: Two 12-inch 45-caliber (Armstrong); twelve 8-inch, 45-caliber; twelve 12-pounders; twelve 3-pounders; four Maxims; four 18-inch submerged tubes (Elswick patent).

The 12-inch guns, which are very similar to the *Dreadnought's* pieces, are carried in cradle mountings similar to those adopted for our new *Dreadnoughts.* The turrets, placed fore and aft in the center line, are extremely roomy. Each

carries a single gun only. This is the most criticised feature of the ship; but it should be borne in mind that a pair of guns in a turret do not make twice as good shooting as a single gun, and—sacrifices being necessary on the displacement—this was probably the wisest that could be made. These 12-inch and also the 8-inch guns are all electrically maneuvered; all hoists also are electric. The big-gun turrets are placed quite clear of all upper works, and have an enormous arc of training, something like 300 degrees, instead of the usual 240 degrees or less. In many positions, therefore, the ship can deliver as much 12-inch fire as the usual four big-gun ship; the 8-inch turret bases extend down to the armored deck, everything being extremely roomy.

The 8-inch guns are carried in pairs in six turrets amidships, the central turrets being raised so as to fire over the end turrets. Eight 8-inch guns can, therefore, fire ahead and have been actually so fired without any inconvenience to the guns fired over. There are no fittings of any sort or kind in the way of these guns, but a perfectly smooth floor ahead and astern. Each upper turret has an actual arc of 180 degrees, the others 135 degrees. The bases of all are heavily armored, and have also armored splinter screens, and there is no diminution of thickness on the inner side.

Eight of the 12-pounders are carried in the amidships battery behind 3¼-inch armor, the remainder, two about the conning tower and two on the similar topside aft.

Fire control is from the top of the conning tower, where there is a heavily-armored station. It is not so suitable, perhaps, as the mast platform of the British Navy, but practically invulnerable, which mast stations are, undeniably, not. Barr and Stroud instruments are now being fixed. The whole of the necessary wires are carried down in a thickly-armored tube, and unlikely to suffer any injury.

The armor protection generally is very great. There is a 10-inch water-line belt amidships, thinning to 6-inch under the turrets and 4-inch at the extremities. It is surmounted amidships by an 8-inch redoubt approximately 160 feet long,

side and bulkheads being of uniform thickness. Thin armor is carried forward to the bow from this redoubt, protecting the whole lower deck. Above the redoubt is the 3¼-inch 12-pounder battery. The conning tower is 10 inches thick and built in stories reaching down to an underwater control station. There are also stations in the forward big-gun turret and the two amidships 8-inch turrets. Great use is made of coal protection in addition to the armor. Normally the ship carries 1,000 tons, but there is room for no less than 2,800 tons.

The principal interest of the *Regina Elena*, however, lies in the engineering department. She is the fastest battleship in the world, being a good deal swifter than even the *Dreadnought*, with which ship, by the way, she shares the peculiarity of a greatly overhung stern. She is 475 feet over all, against 435 feet between perpendiculars.

The propelling machinery, manufactured by the firm of Odero, of Sestri Ponente, consists of two sets of four-cylinder, vertical, inverted, triple-expansion engines, balanced on the Yarrow, Schlick and Tweedy system. These engines are a very fine piece of workmanship. The engine rooms are as roomy as in our big ships. Instead of two large condensers four of medium size are fitted, and appear to be very satisfactory. The dynamo room is also amply large, the switchboard being mounted on a platform high up and clear of everything —there is none of that cramping which might, perhaps, have been expected.

Steam is supplied by twenty-eight Belleville boilers, designed to give 20,000 horsepower. They are in three groups —two of ten each, and one room of eight. These Bellevilles are of a considerably more modern pattern than those with which we are usually familiar in British warships. In main features they do not differ from those in our *Drake* and *Duncan* classes, but there are many refinements of detail. They are, of course, free from that loss of water which characterized our earliest Bellevilles, but that applies equally to any of our more modern ships so fitted. One detail is that the

tubes do not bend to any appreciable extent. In the *Regina Elena*, after one thousand five hundred hours' steaming, the bend in no tube exceeded one millimeter, and there has been a total absence of anxiety about the screw joints. The performance of the boilers on trial is said to have been extremely successful, and apparently this is correct, since Italy, which, after our Boiler Committee's decision, also discarded Belleville generators, has now re-adopted them and ordered this type for all three of the ships recently laid down—*Pisa*, *Amalfi* and another unnamed.

The designed speed of the *Regina Elena* is wrapped in some mystery, as it is variously given as 20 knots, 21 and 22 knots. The contract speed appears originally to have been 22 knots, reduced to 21.5 after the decision to fit this vessel and the *Vittoria Emanuele* as flagships, which involved a good deal of additional weight on the top sides. The other two ships of the class, the *Napoli* and *Roma*, will not be so fitted, and are expected to be about half a knot faster in consequence of this and other weight reductions.

On trial at three-quarter power the *Regina Elena* developed 15,473 indicated horsepower and a speed of 20.33 knots. On the full-power trial about 23,000 horsepower was developed, and the speed was 21.7 knots. For short runs this was slightly exceeded, but 21.7 seems to be about the maximum speed of the ship. On subsequent service trials it was found that with twenty-five boilers alight she could quite comfortably maintain 20 knots for any length of time. The economical speed is 15 knots.

In conclusion, it may be mentioned that the magazines are fitted with special refrigerators to maintain an even temperature of 20 degrees centigrade. There is practically no uncovered wood anywhere in the ship, all the cabin furniture being made of Uralite or some similar asbestos compound. Cupboards, tables and so forth are all of this material, so that there is practically no risk, whatever, of fire in action. The ship is fitted with wireless-telegraph instruments of the usual Marconi type.—"The Engineer."

STEAM TRIALS BRITISH ARMORED SHIPS IN 1907.

Name of vessel	*Agamemnon.*	*Warrior.*	*Minotaur.*	*Shannon.*
Type of ship	Battleship	First-class armored cruiser	First-class armored cruiser	First-class armored cruiser
Builders of ship	Beardmore	Pembroke	Devonport	Chatham
Makers of machinery	Hawthorne, Leslie & Co.	Wallsend Slipway Co.	Harland & Wolff	Humphrys, Tennant & Co.
Displacement, tons	16,500	13,550	14,600	14,600
Type of boilers	Yarrow	Yarrow and cylindrical	Babcock & Wilcox	Yarrow
Heating surface, square feet	50,265	55,534–11,427	73,284	80,424
Grate area, square feet	848.7	971.1–365 4	2,083.8	1,365
First 30 Hours' trial:				
Indicated horsepower	3.494	4,781	5,643	5,849
Speed, knots	11.79 M. M.	14.7 bearings	14.107 M. M.	14.39 M.M., 14,529 throughout the trial
Coal per I.H.P. per hour, pounds	2.15	2.01	1.74	1.96
Water per 1,000 I.H.P. per 24 hours, tons	2.28	3.6	2.9	2.26
Second 30 hours' trial:				
Indicated horsepower	12,023	16,361	19,750	19,621
Speed, knots	17.037 M. M.	20.7 M. M., 19.96 throughout the trial	21.471 M. M., 214 bearings	20.92 M.M., 20.765 throughout the trial
Coal per I.H.H. per hour, pounds	1.9	2.06	1.63	1.83
Water per 1,000 I.H.P. per 24 hours, tons	1.76	3.01	0.92	1.733
Eight hours' full-power trial:				
Indicated horsepower	17,285	23,705	27,856	28,553
Speed, knots	18.735 M. M.	22.46 M.M., 22.409 throughout the trial	23.01 M. M.	22 49 M.M., 22.6 bearings
Coal per I.H.P. per per hour, pounds	2.14	2.33	1.59	2.01
Water per 1,000 I.H.P. per 24 hours, tons	1.56	3.1	1.2	2.6

M. M. = Measured Mile.

TRIALS OF OCEAN-GOING TURBINE-DRIVEN TORPEDO-BOAT DESTROYERS IN 1907.

Name of of vessel.	Type of vessel.	Builders of vessel and makers of machinery.	Type of boilers.	Heating surface.	Speed on six hours' run.
				Square feet.	*knots.*
Cossack...	Ocean-going t. b. d.	Cammell, Laird & Co.	Laird	29,000	33.144 M. M. 33.09 six hours
Tartar...	Ditto	Thornycroft	Thornycroft modified	31,800	35.672 M. M. 35.36 six hours
Ghurka..	Ditto	Hawthorn, Leslie & Co.	Ditto	27,550	33.997 M. M. 33.91 six hours
Mohawk.	Ditto	J. S. White & Co.	White-Forster	29,580	34.5 M. M. 34.245 six hours

TRIALS OF FIRST-CLASS TURBINE-DRIVEN TORPEDO BOATS (NEW TYPE) IN 1907.

Number of boat.	Builders of boat and makers of machinery.	Type of boilers.	Heating surface.	Speed on eight hours' run.
			Square feet.	*Knots.*
3	J. S. White & Co.	White-Forster	8,000	27.077 M. M. 26.385 eight hours
4	Ditto	Ditto	8,000	27.077 M. M. 26.235 eight hours
5	Ditto	Ditto	8,000	27.521 M. M. 26.796 eight hours
8	J. I. Thornycroft & Co.	Thornycroft modified	8,200	27.084 M. M. 27.197 eight hours
9	Ditto	Ditto	8,200	27.196 M. M. 26.734 eight hours
10	Ditto	Ditto	8,200	26.182 M. M. 26.265 eight hours
11	Yarrow & Co.	Yarrow	8,004	27.163 M. M. 27.000 eight hours
12	Ditto	Ditto	8,004	27.206 M. M. 26.814 eight hours
23	Ditto	Ditto	8,004	26.796 M. M. 26.723 eight hours

SHOOTING IN THE BRITISH NAVY.

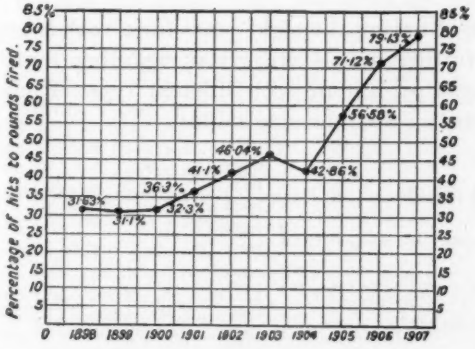
Three blue books have recently been issued by the Admiralty, entitled "Result of Test of Gunlayers with Heavy Guns;" "Result of Test of Gunlayers with Light Q.F. Guns;" and "Result of Battle Practice with Torpedo-boat Destroyers," respectively, for the year 1907. In each of these satisfaction is expressed in varying terms at the improvement shown as compared with former years.

Taking the heavy guns first, we find that as a total 121 ships fired in the trials, and that 1,365 guns were employed, these figures comparing with 89 and 1,073, respectively, for the year 1906. The following table gives the results obtained in those two years:

	1906.	*1907.*
Number of hits	5,733	7,547
misses	2,328	1,991
Total rounds fired	8,061	9,538
Percentage of hits to rounds fired	71.12	79.13

It will be observed from this that although in 1907 there were nearly 1,500 more rounds fired than in 1906 there were over 330 fewer misses, which is a very excellent performance. The last two years have witnessed a vast improvement in the shooting of the Navy, as may be seen from the following table:

Year.	Percentage of hits to rounds fired.
1898	31.63
1899	31.1
1900	32.3
1901	36.3
1902	41.1
1903	46.04
1904	42.86
1905	56.58
Mean	39.74
1906	71.12
1907	79.13



PROGRESS OF NAVAL SHOOTING

It will be observed that the mean of the eight years from 1898 to 1905, inclusive, was 39.74, which is very little more than half the figure obtained last year. It will be observed, further, that, with the exception of a small set back in 1904, there has been a continuous improvement ever since 1899, and that latterly the progress has been very rapid indeed.

The results will probably be better appreciated from the annexed diagram, in which the ordinates represent the percentage of hits to rounds fired in each year.

A new form of target was tried for the first time in 1907, and figures are given showing the comparative practice with the two targets during the year. The reports do not state specifically how this was done, but apparently the 1906 target was used, and a smaller target, which we will call the 1907 target, was marked upon it. The smaller target, of course, modified the results, and this again will be best shown by a table:

	1906 target.	1907 target.
Number of hits	7,547	4,073
misses	1,991	5,465
Total rounds fired	9,538	9,538
Percentage of hits to rounds fired	79.13	42.70

Even with the smaller target, however, the percentage of hits to rounds fired was more than the average with the larger target during the eight years from 1898 to 1905.

Some further details are given regarding the number of hits per gun per minute with different types of gun. These are collected in the following table:

	Target.	Hits per gun per minute.
12-inch and 10-inch	1906	.61
	1907	.40
9.2-inch	1906	3.25
	1907	2.01
7.5-inch	1906	3.48
	1907	1.58
6-inch Q.F. and B.L.	1906	5.93
	1907	3.32
4.7-inch and 4-inch Q.F.	1906	5.73
	1907	2.38

There are several points to be noticed regarding these figures. The first is that there is a slight falling off in the practice made by the 12-inch and 10-inch guns, as compared with 1906, the figure for the latter year being .81. This figure was, however, almost abnormally high, as the average for the nine years, from 1898 to 1906 inclusive, was only

43.71. The 1907 figure shows a satisfactory increase on this. Another point worthy of notice is the excellent practice made with the 9.2 guns. In 1906 the number of hits per gun per minute was 2.84; and in 1905, 1.40. For the seven years previously the number had never risen above .73, and the average was just under .41. The 1907 figure is nearly eight times better than this average. The 9.2-inch gun was also wonderfully successful with the 1907 target—even more so, in fact, than the 7.5-inch gun. Both the 6-inch and the 4.7-inch guns show satisfactory increases in the number of hits per gun per minute, the 1906 figures having been 5.68 and 4.96 for the two types of gun respectively. In both cases there has been a practically continuous improvement since 1898, when the figures were 1.11 and 1.68, respectively.

Turning now to the test of gun layers with light, quick-firing guns, the results of the three years 1905–6–7 are given in the following table:

	1905.	*1906.*	*1907.*
Number of ships that fired	86	89	122
guns	1,118	1,421	1,898
hits	2,228	4,666	7,462
misses	8,291	8,845	10,272
Percentage of hits to rounds fired	21.63	34.53	42.08
Hits per gun per minute, 12-pounders	2.12	3.417	4.471
Hits per gun per minute, 6-pounders and 3-pounders (except Vickers)	1.97	3.358	3.64
Hits per gun per minute, 3-pounders (Vickers)	...	8.144	6.74

Very little comment regarding this is required. The number of misses is undoubtedly large, but on the other hand the percentage of hits to rounds fired shows a satisfactory increase, and is, indeed, very nearly double what it was in 1905.

An interesting comparison may be made between the figures in the foregoing table and those given in Blue book dealing with the result of battle practice from torpedo-boat destroyers. These are set out in the following table, the years 1905–6–7 again appearing:

	1905.	1906.	1907.
Number of ships that fired	57	52	121
guns	342	312	669
hits	653	1,004	2,069
misses	2,608	1,898	3,709
Percentage of hits to rounds fired	20.02	34.6	35.81
Hits per gun per minute, 12-pounders	1.54	2.43	3.97
6-pounders,	1.98	3.73	3.57

The 1907 figures do not in this case show the same improvement, and it is rather a pity that no details are given regarding the relative conditions under which the tests were made.

Space does not permit of us going further into the contents of these Blue books, but the detailed data regarding the performances made by each particular vessel taking part in the tests are of much interest.—"The Engineer."

ITALY'S PROGRESS IN SUBMARINE NAVIGATION.

It is not commonly recognized how rapid and brilliant have been Italy's strides in the direction of submarine navigation. While most other nations engaged in like work have permitted a good deal of spectacular publicity, Italy has gone along in a quiet and unobtrusive manner with some experiments that have quite revolutionized the accepted standards in this fairly new branch of naval architecture.

From the first Italy has stood for the submersible, and the boats now possessed by Italy are typical of all that is best in this particular type of under-water craft.

The *Delfino* was the first of Italy's modern submarines. She was built in 1889. At that time she was a cigar-shaped craft, propelled by electricity and fitted with two 14-inch torpedo tubes. Her speed on the surface was not more than five knots, and when submerged she could not exceed a speed of two knots. To enable the boat to sink on an even keel and, in fact, to control her submergence, she was fitted with a couple of propellers set in vertical tubes running through

the boat, somewhat after the plan adopted by Nordenfelt in his boat built for the Russian Government—generally known as *Nordenfelt IV.*

While the results obtained with the *Delfino* in her original form were not altogether satisfactory, still she provided a fund of practical data which was properly estimated by the Italian authorities, and afforded a safe foundation for further development and trials. From 1889 until 1901 the *Delfino* was used for extensive experimentation, the results of which were carefully kept secret by all the officials concerned. In 1902, or thereabouts, the *Delfino* was considerably modified and underwent extensive improvements in a number of directions. As originally built, her upper-hull plating was made considerably heavier than the rest of her spindle-shaped body. In rehabilitating the craft, this heavy hull plating was removed and a great saving in weight thus effected, which was promptly put to better and more telling use in other directions. A set of up-to-date accumulators were installed in place of the old battery, and explosion motors were provided for the purpose of supplying power for surface propulsion. This gave the *Delfino* dual means of propulsion, the electric power being for submerged work only. The spindle-shaped hull had proved an undesirable form for surface navigation, and to make the boat more weatherly she was fittted with a superstructure something after the fashion of that now fitted on the British and American boats of the *Holland* type. Thus modified and modernized, the *Delfino* possessed a surface speed of 8 knots and a submerged speed of something over 6 knots. Two 18-inch torpedo tubes supplanted the two old 14-inch tubes, and altogether the *Delfino* has since shown herself to be an efficient and reliable craft.

The valuable information secured in the gradual evolution of the *Delfino* formed the groundwork upon which Engineer Cesare Laurenti worked in designing his boats of the *Glauco* type, which were launched successively in 1905, '06, '07. These vessels are 118 feet long, have a maximum beam of a trifle over 13 feet, and a surface displacement of 150 tons.

They are said to have developed a speed of 14 knots when running light upon the surface and a speed of 8 knots when running submerged. In the summer of 1906 these boats took part in the Italian naval maneuvers, and their performance was highly satisfactory during their work both by day and by night. Their mobility was amply demonstrated during the run from Venice to Taranto, which they made without convoy and entirely under their own power. Their part in the maneuvers consisted principally in making attacks upon anchored ships guarded by a large flotilla of torpedo craft. The *Glauco* and *Squalo*, while running at depths of from 10 to 20 meters, experienced no difficulty in passing through the narrow strait of San Vito and reaching the anchored battleships without once being detected by the guarding flotilla. These achievements, and the facility with which the boats were handled after only a short period of training on the part of their crew, gave the amplest evidence of the degree of perfection reached in their design and construction. It is the best sort of proof that the submerging boat in contradistinction to the diving boat is by far the easier craft to learn to handle; and this point has an important bearing upon the wartime usefulness of such vessels, when rapid changes or substitution in the crews may become necessary, and the ease with which a stranger may take up this work will mean everything to the military usefulness of such craft. An Austrian technical journal, commenting upon the performance of the *Glauco* and *Squalo* during the Italian manuevers, had this to say:

"The results achieved with the submarine boats at Taranto have confirmed the trials made with these vessels at Venice, and have shown that they are capable, especially by night, of approaching moored objectives and getting within an effective firing range of 800 meters. Furthermore, the performances at Taranto, have also proved that the Italian submarine craft possess exceptional firing apparatus for their torpedoes; and, in fact, it may be rightly claimed that the Italian Navy has made more progress in submarine navigation than any of the other first-class Powers, not even excepting France."

Coming from an Austrian critic this praise is very significant, because, when not acting upon the defensive, these Italian submersibles could have for their objective no other purpose than to attack the Adriatic ports of Austria.

In addition to the *Glauco* and *Squalo*, the Italian Government now has three other sister ships, namely, the *Narvalo*, the *Otaria* and the *Tricheco*. With these vessels the Italian Government has been recently carrying on a further series of experimental maneuvers, and from authoritative sources it is learned that their performances have served still further to emphasize the advanced position taken by Italy in the direction of submarine navigation.

Engineer Laurenti now has other boats under construction for the Italian Government, as well as for some northern countries. These boats are being built at Spezia, at the shipyard of the Fiat San Giorgio, the latter yard having gone in for specialization in the matter of submersible torpedo boats.

Some very interesting details regarding these vessels have leaked out, and this material is well worth reproduction. The following are their principal dimensions and general characteristics:

Length over all, feet and inches	139–04.5
Beam, extreme, feet and inches	16–10
Freeboard (hull), feet and inches	3–11.25
(hatch coamings), feet and inches	5–04.75
(to top of conning tower), feet and inches	10–09.75
Draught (surface trim), feet and inches	6–10.5
Displacement, surface, when fully laden, tons	180
submerged, tons	230
Safety drop keel, tons	12
Reserve buoyancy, in light condition	60 per cent. of displacement.
Metacentric height, surface trim, inches	19.6
submerged, inches	11.8
Number of bulkheads	8
Hull designed to withstand submergence to depth of, feet	150
Maximum power of explosion motors, horsepower	750
electric motors, horsepower	190
Number of propellers	3
Surface speed, maximum, knots	15
Submerged speed, maximum, knots	9
Surface radius of action at 8 knots speed, nautical miles	875

Submerged radius of action at 5 knots speed, nautical miles.....	40
Total fuel capacity, cubic feet.....	296.6
Compressed air in reserve, at 2,100 pounds pressure per square inch, cubic feet.....	13,773
Number of air compressors.....	2
Number of centrifugal pumps (for water ballast).....	2

Each pump can discharge 130 tons per hour at a depth of 130 feet.

Each pump is driven by a special motor.

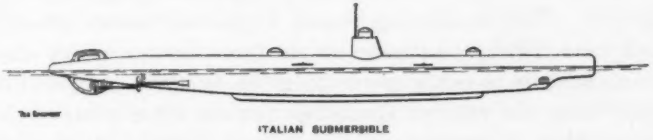
(1) *Speed.*—The best French boats do not exceed a surface speed of 12 knots, and this applies to vessels of 400 tons. The British boats of 300 tons of the C class make only 13 knots. It will thus be seen that the Italian boats have accomplished a great deal more on a very moderate displacement.

(2) *Reserve Buoyancy.*—The Italian boats, when running in light trim, have a reserve of buoyancy of 60 per cent. of their displacement. The French under-water craft of the *Aigrette* type have about 20 per cent. reserve buoyancy. The *Lake* type have 22 per cent., while the general run of the *Holland* boats have hardly 10 per cent. Even when water is admitted to the superstructure, the Italian boats retain a reserve of buoyancy of 30 per cent. It will thus be seen how seaworthy these vessels should be and what a large margin of safety they have against damage due to collision or any shock producing leaks.

(3) *Stability.*—The Italian boats stand quite alone in the point of considerable metacentric height when submerged. As has been said, the metacentric height in that condition is nearly 12 inches. In the large English boats of 300 tons displacement the metacentric height is only 9 inches, while in boats of the *Lake* type and *Protector* class it is only 7.2 inches. This gain in metacentric height adds very materially to the longitudinal stiffness of the Italian boats.

(4) *Submerged Navigation.*—The Italian boats can be submerged at once, and on an even keel, after a brief preparation in trimming from surface condition. The time required to adjust water ballast for this purpose is only five

minutes, which has not been accomplished by any other submersible or submarine up to date. The boats retain a positive buoyancy, and submergence is effected by means of two special propellers, which force the boats vertically downward. The various other submarine vessels in existence can be submerged only when under way if retaining a reserve of buoyancy. One would have to give these other vessels negative buoyancy if submergence on a level keel were desired. This would be a dangerous operation, as it would then be difficult to prevent the craft from sinking below the predetermined depth. The *Porpoise* sank in this manner and narrowly escaped destruction, and the *Octopus* did the same thing during her official acceptance trials, but, fortunately, the bottom was not so far away as in the case of the *Porpoise*. The Holland boats submerge when under way at an angle of 10 degrees to 12 degrees until the desired depth has been reached. This depth, however, can only be maintained by the exercise of great care and skill on the part of the operator at the horizontal rudder. Therefore, submerged navigation in shallow water at high speed with boats of the diving type is a very dangerous operation. The Italian boats run submerged with a change of longitudinal trim of not more than 1 degree to 2 degrees at the very most, and with a variance in vertical movement of less than 20 inches.



ITALIAN SUBMERSIBLE

(5) *Motive Power.*—The Italian boats are driven by three propellers. The middle screw serves for cruising purposes, while all three are in motion when running at full speed. For submerged navigation the side screws only are operated. When running at cruising speed the central screw alone is used at full power. The motors can thus be used at all times to the best advantage. By a simple adjustment of the mag-

netic fields the electric motors used for submerged navigation can be so cut down in the number of their revolutions that they can be operated efficiently at the modest rate of 25 per cent. of their high speed, and that without diminishing the tension. Switches for the batteries are thus done away with. The accumulators themselves are small and handy. The weight of one unit amounts to only about 250 pounds. Their removal in case of accident is, therefore, much facilitated. With the heavy cells carried by the Lake and Holland boats, this operation is a most difficult one, because each cell weighs not less than 1,200 pounds. The battery is hermetically sealed, and the gases developed are expelled outboard by special means. Hence the danger of an explosion by reason of these gases—which has been proved fatally great in some other submarines—is accordingly greatly reduced in the case of the Italian boats. The explosive motors are driven by benzine. Up to the present time this is the only fuel permitting the construction of light motors of sufficient power to produce high speed. The manner of stowing the benzine and arranging its feed to the motors are such that no annoying features have manifested themselves at any time since these vessels were put in active service.

(6) *Division by Means of Bulkheads.*—The interior of the Italian boats is divided into eight separate watertight compartments. In this feature the Italian boats are distinctly unique. This divisioning makes it possible to seal hermetically and divide the engine rooms from the remaining divisions, and, by so doing, preventing the heat and any possible gases from the engines spreading into the other parts of the boats when submerged. Submergence is not delayed until the engine space has cooled down. It is simply closed at once and allowed to take care of itself until the boats are ready to return to the surface and to resume there propulsion under engines. Furthermore, the safety of the craft is considerably augmented by this system of subdividing. The serious accidents that befell the French and English submarines showed plainly the need of subdividing by means of

watertight bulkheads. During the last Italian maneuvers the submarine boat *Squalo* continued to run submerged, despite the fact that she carried more than a ton of water in her engine room, which had gained admission there by reason of a defective valve of the water jacket of the motors. The American submarine *Shark* lost her reserve buoyancy through a leak in her engine exhaust valve, and very narrowly escaped going to the bottom in 1904. In the case of the *Shark*, only a few pounds of water thus leaked into the vessel, yet it was enough to imperil her.

(7) *Torpedo-Firing Tubes.*—The Italian boats carry two bow torpedo tubes with their forward ends so formed that they offer but very little resistance to the water. These torpedo tubes, which are capable of carrying 18-inch torpedoes, are so placed that they lie somewhat back and below the stem, so that they are safeguarded in case of bow-on collision.

(8) *Hull.*—The hulls of the Italian boats are not formed with the customary circular cross-section with a superstructure. They are built upon a patented system, and in form are quite like the ordinary torpedo boat. Apart from giving the vessels easy lines for surface speed, this particular construction admits of a very convenient arrangement of the machinery. The extreme bow and stern ends of the vessels are high enough inside for a man to stand upright. Because of their special form it is possible to mount in the Italian boats more powerful motors, larger accumulators and bigger pumps than are permissible upon the same displacement in submarine vessels having the usual spindle form of main hull. Even though the Italian boats have not the circular cross-section recognized as being that best capable of resisting high compression, still they are able to withstand safely a submergence of 150 feet, if such be required.

(9) *Sighting Instrument.*—The Italian boats are equipped with two sighting instruments for submerged navigation. These instruments are of the Russo-Laurenti type, and possess a field of vision of 50 degrees. The portion extending

above the surface has a diameter of about 3.5 inches. The instrument is so designed that the eye piece gives a large image, and does not require the observer to keep his eye constantly fixed thereon. In this way eye fatigue is avoided and continual observation can be had without any of the tiring stress common to the general run of these instruments. The instruments are so arranged that they give normal vision and magnified vision, the latter being designed to enable the observer to distinguish distant objects and to read correctly visual signals.—"The Engineer."

H. M. S. *SWIFT.*

A vessel which will, it is claimed, prove when completed to be the fastest in the world was successfully launched from the shipbuilding yard of Cammell Laird & Co., Limited, Birkenhead, December 7, in the presence of a large concourse of people. The *Swift*, the name by which the vessel will be known, is being built for the British Admiralty to meet the requirements of a special type of ocean-going torpedo-boat destroyer, and is of considerably larger dimensions and higher speed than any former vessel of the destroyer class. She is designed for a speed of 36 knots per hour as against the 33 knots of the *Tribal* class of sea-going destroyers.

Her principal dimensions are: Length between perpendiculars, 345 feet; breadth, 34 feet; depth, 20 feet 4 inches; with a displacement at her mean load draught of about 1,800 tons. Her armament consists of four 4-inch breech-loading guns, two on the forecastle and two on the upper deck, and two 18-inch torpedo tubes on the upper deck. She will be propelled by quadruple turbine machinery of the Parsons type manufactured by Cammell Laird & Co., Limited, at their Birkenhead works. As in the new large Cunard vessels, the turbines will drive four shafts, there being one propeller on each shaft. The turbines are placed in two distinct engine rooms in order to minimize the capacity of any one water-

tight compartment, and several novelties have, we are informed, been introduced in order to accommodate machinery of the large power required in the comparatively small space at disposal.

There is an installation of twelve boilers of the Express straight-tube type, these being arranged for the burning of oil fuel. The boilers have been built by the firm at their Beaufort-road works.

THE PROGRESS OF THE TORPEDO.

As vital national issues are dependent upon munitions of war, it is universally agreed that their efficiency should not in the slightest degree be weakened by unsatisfactory details, least of all on the score of expense. This view further requires that every unit constituting the complete implement of war must be of the most approved form. The fastest cruiser with anything short of the most powerful guns possible within the limits of weight permitted by general considerations of design would not be satisfactory. A battleship well armored, with the best of propelling machinery, and with the most reliable of guns, would be a source of weakness to a fleet if her gun mountings were unsound. Such points are often forgotten in elaborate statistical comparisons of the fleets of different Powers, and yet they are almost as important to fighting efficiency as the skill and experience of the personnel. In the measuring of relative efficiency, the only substitutes for the test of actual warfare are the maneuvers, which are more extensive in the British than in other services. A comparative study of contemporaneous progress in the mechanical sciences associated with peace and war industries further enables one to appraise with moderate accuracy the official attitude towards appliances which give reliable promise of increasing the efficiency of weapons of warfare. The evidences afforded by these two standards of measuring progress are reassuring so far as the British Navy is concerned. In recent years the tendency has been distinctly progressive.

The existing exceptions are, as a consequence, the more surprising, and call for the keener criticism.

One of the most important instances where there has not been a ready response to successful unofficial effort towards improving war munitions is in the case of the torpedo. Recently we have placed on record the splendid results achieved by torpedo-boat destroyers, which realized speeds of from 33 to 35 knots, and now we have in a paper read before the Liverpool Engineering Society by Mr. E. C. Given convincing proof of the success of the submarine or submersible boat. All is thus well with the vessels which are to use the torpedo as a weapon of war. But when measuring the significance of the efficiency of these surface and submersible torpedo-firing boats, it is imperative that the efficiency of the torpedo itself should be considered. If the most effective weapon is not used, the best cannot be got from the boats. It is idle to increase the expenditure of a surface boat from £70,000 to £120,000, to get 34 knots instead of 30 knots, and at the same time accept a torpedo which has a speed of only 24 knots at 3,000 yards range, when there is available a weapon of 32 knots speed at the same range, and particularly when other Governments are adopting the new instrument. Modern naval tactics favor long range, and the torpedo which has a speed of 28 knots at 4,000 yards range will be immensely superior to one of from 18 to 20 knots at such range. The advantage is correspondingly greater at shorter range. Indeed, the formerly approved practice of fitting bow tubes to warships had to be discontinued because the speed of the torpedo-boat, and even the cruiser, was approximately so nearly to that of the torpedo itself. When, in 1886, the 125-foot torpedo boats could overrun the torpedo then available, the Mark IV Fiume torpedo was introduced, and gave the necessary improvement in speed, but only for the short range of 600 yards. Some years ago the same difficulty of relative speed again arose, and the bow tube was abolished. The best torpedo in the Navy at 1,000 yards range has a speed of only 35 knots, and at 1,500 yards range 30 knots. Destroyers

of 33 to 35 knots would thus overtake the torpedo they had fired ahead in less than two minutes. Thus with low-speed torpedoes any attempt to fire ahead would be attended by serious danger.

Now torpedoes are available which have a speed of 43 knots at 1,000 yards, and of 40 knots at 1,500 yards; so that, if these were adopted, we could return with greater safety to the bow tube, which has great advantages. A destroyer approaching the enemy bow on, alike in open sea or restricted waters, presents a much smaller target, can fire the torpedo more easily, and, reversing engines, can escape backwards more quickly. Thus it used to be a condition of the contract, in some foreign navies—if not also in the British service—that a given astern speed should be realized on trial. The contingency that the charged point of a torpedo in a bow tube, being above water, was likely to be struck by a projectile, scarcely holds, since above-water tubes are fitted elsewhere in the latest ships.

The splendid results achieved by the latest torpedoes, giving an increase in speed of about 10 nautical miles per hour at all ranges, has been achieved by the application of air heaters. It is now some years since the world was startled with rumors from America of the extraordinary results achieved by the Bliss-Leavitt apparatus for heating the air of torpedoes, and from that time the firm of Whitehead & Co. have devoted considerable attention to the investigation of this subject. Having taken over the patents of Sir W. G. Armstrong, Whitworth & Co. in connection with heating devices, they have succeeded in producing a heater considerably more efficient than was accredited by rumor to the Bliss-Leavitt. The heater consists of a small steel chamber between the air vessel and the engine of the torpedo, in which a certain amount of liquid fuel is burnt in conjunction with the air passing to the engine, resulting in a gain in power of 100 per cent. as compared with the same engine and air vessel when run cold. It is, however, in the extreme simplicity and safety of the Whitehead hot-air torpedo that

its chief claim to superiority lies. The whole apparatus takes up only about 3 inches of the torpedo's length, and weighs about 12 pounds. Details of construction are, of course, only known to the makers; but they are such that no difficulty is experienced in handling the torpedo by any man acquainted with this weapon. In order to show clearly the advantages which have been obtained by thus heating the air, the following table gives the speeds at various ranges of the latest Whitehead torpedo when run cold and hot; and, in this connection, it may not be out of place to remark that the latest Woolwich torpedo does not equal the Whitehead as regards speed at any range:

TABLE SHOWING SPEEDS OBTAINED BY THE LATEST WHITEHEAD 18-INCH TORPEDO.

	With cold air.	With hot air.
At 1,000 yards, knots	35	43
1,500 yards, knots	30	40
2,000 yards, knots	28¼	38
3,000 yards, knots	23 to 24	32
4,000 yards, knots	18 to 20	28

As we have already said, foreign countries are showing keen interest, and are acquiring torpedoes fitted with this heater; and at the present time the United States Government are obtaining these weapons from the Whitehead Company at Weymouth, whilst the Whitehead Works at Fiume are extremely busy with orders from European Governments and some States of South America. At the present time, we understand, the British Admiralty has, so far, not followed the example of foreign countries. It is impossible for the Admiralty to long delay equipping the Fleet with the torpedoes so markedly superior to those of the Government's own construction, in view of the activity displayed by other countries in providing themselves with complete equipments of this weapon.

The importance of having the very fastest torpedoes available is great, not only on the grounds that the torpedo should, at least, be faster than the torpedo craft, but also because the errors which are of necessity present in practice with these

weapons are very much reduced as the speed increases; and the possibility becomes more remote of the enemy avoiding a torpedo when its track discloses its progress. As the result of a large number of runs with the Whitehead hot-air torpedo at Portland, it was clearly shown that for steadiness of running, both for speed and direction, the hot-air torpedo is superior to the same torpedo when running cold; this superiority being more marked in cold weather, as after the water temperature has dropped to about 40 degrees F. it is impossible to run the ordinary cold-air torpedo. Thus every consideration establishes the great importance of the adoption of the new weapon, and until this is done the best cannot possibly be realized from the improvements achieved with our torpedo craft.

The unceasing work done by the naval architect and marine engineer to improve the craft, while the torpedo authorities seem to be standing still, can be easily demonstrated. One instance must suffice here. Our new destroyers, of 790 tons' displacement, steam 34 knots for 11.36 tons of oil fuel per hour, and continue thus on official trial for six hours, while ten years ago the boats of limited capacity and radius of action, because of only 360 tons' displacement, required 8 tons per hour for 30 knots, and even then could keep this up for only three or four hours. The engine power has had to be trebled, and yet the weight of fuel used is increased only about 40 per cent.

The paper read by Mr. Given indicates that corresponding progress is being made with submersible boats. He deals with the vessels built for all Powers. In the British boats, which have increased in displacement from 120 to 500 tons, the surface speed has been augmented to the extent of about 75 per cent.—from 8½ to 15 knots—while the submerged speed has increased 30 per cent.—from 7 to 9 knots. It will be realized that great difficulties are associated with increase of speed, especially submerged. The power then utilized is electric, and the current must be stored in batteries. Thus, while the oil engines used for propulsion, according to Mr.

Given, weigh about 56 pounds per brake horsepower, the weight of the electric mechanism is 235 pounds per electric horsepower. Strategists are not, however, agreed as to whether high speed, when submerged, is necessary. Mr. Given says: "The surface speed is the strategic speed, enabling the vessel to quickly reach or leave the fighting zone; whereas the submerged or tactical speed is of less importance (except for attacking moving vessels), as when submerged they are unseen; and it is thought that the only means of attacking a submarine is with a spar-torpedo, and this is extremely difficult to carry out, as the submarine can dive or maneuver out of reach if the water be deep enough." With increased length there is a possibility of increased surface speed, but the fine ends of the ordinary surface boat cannot be approximated.

The proportion of length to beam in submersibles has undergone a great change. The earlier British boats had a length of about five times the beam, and the later ones of about ten times the beam. The increased length tells against the diving and maneuvering, especially in shallow and confined waters, so that the problem of speed is one of great difficulty, particularly if the success hitherto achieved—notably with British vessels—in connection with maneuvering and quick diving is to be continued. No doubt the speeds will increase, and we shall at an early period have submarine boats corresponding in speed to the battleships, with equal radius of action and good sea-going qualities. That being so, there is the greater need for an active policy at the Admiralty in connection with torpedoes, without which the submarine or surface torpedo boats are practically useless. We have no doubt that Parliamentary pressure would result in a more courageous policy in this matter. We cannot believe that the question is one of economy. No doubt the replacing of the existing torpedoes of deficient range by the latest instruments would involve a considerable sum, but when it is considered that the efficiency of vessels, costing millions of

pounds, is greatly lessened by the absence of the best torpedo, only "economists at all costs" would oppose any proposal for adopting the new torpedo.—"Engineering."

VANADIUM STEEL IN THE UNITED STATES.

Several interesting experiments and developments in the manufacture and use of vanadium steel have been made in the United States. The American Vanadium Company has developed five grades of steel, the character of which is shown in the accompanying Table No. 1. These are kept as free as possible from sulphur and phosphorus. Sulphur may be as high as 0.035 per cent. With phosphorus up to 0.02 per cent., the silicon may be as high as 0.10 per cent. in the first three and 0.15 per cent. in the fourth grade. With phosphorus as high as 0.03 per cent. the silicon should not exceed 0.05 to 0.06 per cent. in the first three grades or 0.10 per cent. in the fourth.

TABLE 1.

	No. 1.	No. 2	No. 3.	No. 4.	No. 5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Carbon	0.25 to 0.30	0.20	0.20	0.45 to 0.55	0.12 to 0.15
Vanadium	0.16 to 0.18	0.12	0.16	0.18	0.12
Manganese	0.40 to 0.50	0.30 to 0.40	0.40	0.80 to 1.00	0.20
Chromium	1.00	0.50	0.80	1.25	0.30

With steel No. 1 three methods of heat treatment were employed: First, annealing at 800 degrees centigrade for one or two hours, and then cooling in air or ashes according to the character of the work; secondly, quenching from 900 degrees centigrade in lard or fish oil and then annealing for from one and a half to two hours; thirdly, quenching from 950 degrees in lard oil and letting down at 360 degrees for 15 to 30 minutes in a lead bath and then cooling in air. This grade of steel treated by the first process is suitable for light axles, connecting and coupling rods, driving axles and piston rods. If treated by the second process it is employed for crank shafts, crank pins, transmission parts and gear wheels. Steel No. 2 requires no special heat treatment and is intended for

axles, rods and parts in which strength to resist torsion is of importance; it is also used for large machine bolts. Steel No. 3, which also requires no special heat treatment, is suitable for axles, rods and bolts. Steel No. 4 may be subjected to the following heat treatment: First, annealing at 800 degrees centigrade for one hour and cooling slowly down to 600 degrees, care being taken not to chill the steel by too rapid reduction of temperature. With this treatment the steel is suitable for solid-center, railway-carriage and wagon wheels, crank pins and gun barrels. Secondly, quenching in oil from 900 degrees centigrade and drawing back at 450 degrees in a lead bath, then cooling in air. With this treatment the steel is adapted to springs for locomotives, automobiles and carriages. Steel No. 5 is subjected to the ordinary case-hardening process, and is used for ordinary machine and engine parts. The results of tests of ordinary "carbon" steel, nickel steel and vanadium steels of a grade adapted for automobile work resulted as in Table No. 2.

TABLE 2.—TESTS OF STEELS.

.....	Axle-steel.	Nickel axle steel.	Vanadium steel No. 1 with heat treatment.		
			No. 1.	No. 2.	No. 3.
Yield point, lb. per sq. in...	41,300	49,270	63,570	110,100	224,000
Ult. strength, lb. per sq. in.	65,840	87,360	90,080	127,800	232,750
Ratio, per cent.....	62	56	66	87	96
Elongation in 2 in., per cent.....	42	34	33	20	11
Contraction of area, per cent.....	61	58	61	58	39
Torsional twists.....	2.6	3.2	4.2	2.5	1.8
Alternating bends.....	10	12	18	10	6
Pendulum impact, ft-lb.....	12.3	14	16½	12	6
Alternating impact, number of stresses.....	960	800	2,700	1,850	800
Falling weight on notched bar, number of blows.....	25	35	69	76	...
Rotary vibrations, number of revolutions.....	6,200	10,000	67,500	...	...

Cast-steel frames for locomotives have been made with vanadium steel by the Union Steel Castings Company. Five frames were made from one heat for four, six and eight-

coupled engines, the weight of each frame being from 4,400 pounds to 5,600 pounds. The steel poured quietly and the frames were finished satisfactorily. It was stated that this heat was the best ever made, and it is considered that the use of vanadium will result in producing castings more nearly perfect and solid than those of ordinary carbon steel. It is not detrimental to the quality of the steel with regard to resistance to static strains, while the vanadium steel is decidedly superior to ordinary steel when dynamic stresses have to be resisted. The company has issued a statement relative to its experience. From this we abstract the following:

"We form test bars of 8 inches with $\frac{1}{2}$ inch connection. To detach one of these test bars from an ordinary steel frame requires from six to twelve blows with a 10-pound sledge. Test bars on a frame made of vanadium steel required from 100 to 150 blows by the same man with the same sized sledge. The fracture of vanadium steel is closer and presents a much tougher appearance than ordinary steel. Two samples were tested in a vibratory machine deflecting a bar 7 inches in length and $\frac{5}{8}$ inch diameter, $\frac{1}{8}$ inch on each side of the center, making $\frac{1}{4}$ inch deflection. The average number of vibrations required to break a bar of ordinary steel was 4,206, while the average number of vibrations required to break a bar of vanadium steel was 12,776.

"We also bent a sample of ordinary steel and one of vanadium steel to an angle of 90 degrees, and reversed them by bending in the opposite direction to an angle of 90 degrees. The ordinary steel bent three and one-half times before breaking, and the vanadium bent four and one-half times. In bending a $\frac{1}{2}$-inch by 1-inch test bar of vanadium steel on a single bend under a hammer, it was bent flat on itself without fracturing or shearing. A similar sample of ordinary steel of same analysis, except as to vanadium, also bent flat on itself but sheared slightly.

"If the carbon were increased in the ordinary steel so as to give a tensile strength of 77,800 pounds, it would give almost, but not quite, as good results in elongation and reduction as

vanadium steel. The elastic limit, however, would probably fall about 5,000 pounds below that obtained with the vanadium steel. In view of the fact that the bending bars of vanadium steel were over 77,000 pounds in tensile strength, while those of ordinary steel were slightly over 68,000 pounds in tensile strength, we come to the conclusion that the results obtained indicate that the vanadium steel is very much tougher than the ordinary steel. If ordinary carbon steel of 77,000 pounds tensile strength or over had been used in making the bending and vibratory tests, the results would have been very much inferior to those obtained from the lower carbon steel."

In planning the vanadium-steel frames, the tool was made to take the same cut as with ordinary cast-steel frames. The metal was found to be harder and tougher and more difficult to cut, but not sufficiently to affect the time of machining. The chips of vanadium steel were much larger, tougher and more regular than those from ordinary steel.

In a welding test, two pieces were welded together and then planed to a section ½-inch by 1-inch, for the testing machine. The fracture indicated that the weld was not quite perfect on one side, and it left a slight fin. The bar did not break, however, until a pull of 72,460 pounds had been reached.—"The Engineer."

MECHANICAL POINTS IN CONNECTION WITH STEAM TURBINES.

The feeling of untrustworthiness which for so long was the predominant note in connection with turbine work dies hard, and is still very rampant in many quarters. A veil of secrecy necessarily accompanies the development of such a revolutionary prime mover, and consequently many of the difficulties which occur gain an undue importance in the eyes of those not intimately acquainted with turbine construction. Apart entirely from the question of economical fuel consumption, the success of a prime mover depends on its reliability for continuity of operation. It is natural to expect that mechan-

ical troubles not hitherto experienced should be met with, but it is surprising what a large proportion of the troubles which have been experienced and have contributed to the creation of this feeling are due to causes which are not inherently embodied in the turbine principle. Had the same details and methods been used on reciprocating engines, trouble would have certainly followed. These remarks are not confined to any one type of turbine, or to those constructed in this country. Engineers in all parts of the world are actively engaged in turbine development, and it is very striking how universal the custom is to treat the accessory details as requiring special and novel designs.

In contradiction to this view it may be taken that the details will ultimately become simplified into similar designs to those which have proved themselves on reciprocating engines. In this article some of these points will be considered, and to avoid repetition commencement will be made at the steam inlet, and the other parts will be taken in sequence through the machine.

Steam Pipe.—With some of the methods of connection adopted this has proved a fruitful source of cylinder distortion. The longitudinal expansion of the cylinder must be provided for, in addition to that of the steam pipe. The length of pipe connecting to the cylinder should be a bend of sufficient elasticity to take up the expansion without putting any undue stress on the cylinder. The end remote from the cylinder must be securely anchored, so that the rack and strain of a long length of piping is isolated from the cylinder. Anchoring the pipe also prevents vibration being transmitted to the steam range. The high-period vibration of a turbine, although of small amplitude, often coincides with the natural period of vibration of the piping, and causes the latter to dance violently. In support of the contention at the commencement, it may be remarked, in passing, that this is precisely what is necessary in connection with reciprocating engines; yet almost every one connected with turbine work has experienced much trouble from neglect of this simple precaution, and it

will be noticed that a similar parallel exists in many other cases.

Cylinder.—The usual trouble experienced here is distortion, which may be caused by temperature or external forces. If the steam and exhaust connections are properly made, and the chest containing the governor valve, &c., suitably supported when placed on the side, it resolves itself into a question of design. The horizontal joint is an addition to the problem, but in many respects it is akin to that which has to be faced with large steam-engine cylinders. In one respect it has the advantage, for it has no rapid and continuous changes in temperature to withstand. After it is once heated up it remains approximately the temperature of the steam with which it is in contact right through, from inlet to exhaust.

Ribs and branches should be avoided wherever possible, and the barrel retained as a plain cylinder. After rough machining and before finishing, the castings should be annealed at a temperature of about 1,000 degrees F., to relieve all casting stresses. This is especially important when highly superheated steam is used. Although a turbine can be started up cold without the risks attendant on similar treatment of a reciprocating engine, it is obviously inadvisable to do so unless under urgent necessity. The more gradual and thorough the heating-up process, the less likelihood of distortion, as the flanges and facings will have time to warm up in addition to the thinner barrel metal. The methods of supporting and securing the cylinder for reaction turbines must be carefully designed to prevent hogging. Many a blade strip has occurred through neglect to ensure free longitudinal expansion. The distribution of the non-conducting material used also demands careful consideration, and the horizontal flanges must be well covered. The covering over the flanges must be made removable to allow of lifting the top half of the cylinder, and neglect to replace it before starting up has led to disaster. A moment's reflection will make the reason apparent.

The Revolving Element.—The objects to be attained are rigidity and balance. So long as the deflection does not

exceed a certain amount, and accurate workmanship with homogeneity of metal are ensured, rigidity and balance can readily be obtained. The parts can be either forced or shrunk together and secured in various ways. That parts of spindles have worked loose in service emphasizes the necessity of special attention being given to providing positive locking arrangements. A good method of construction is that of forcing on with only sufficient forcing allowance to insure a a good fit, in which case a key must be provided to transmit the turning moment. This enables the various parts to be finished and balanced before assembly, which materially facil tates the balancing of the complete spindle, there being no distortion from the forcing.

Couplings.—Most of these troubles have been due to defects in lining up, or insufficient contact surface causing wear and tear, with consequent heating and vibration. It is questionable with some designs how much flexibility in the horizontal direction actually exists when the plant is running on load. The generator shaft should have ample bearing collars to restrict the longitudinal movement, so that driving is the only duty which the coupling has to perform.

Main Bearings.—Contrary to natural expectations, little trouble has been experienced here. The troubles which have occurred have been mainly due to defective lubrication. Bearings of the sleeve type are desirable for speeds of 2,000 R.P.M. and upwards, but below 2,000 R.P.M. solid bearings of cast iron, babbitted, are quite satisfactory. The seat should be spherical, and the shell of ample strength. The two halves of the bearing must be securely bolted together to prevent any springing in the overhung parts. Although water cooling has been provided on very large bearings, it is better to dispense with water cooling, and to supply a sufficient quantity of oil to carry off the heat. The water connections on spherical-seated bearings are liable to leak and give trouble with the oil. The lubrication of bearings will be considered under "Oil Service."

Thrust Bearings.—Although the primary purpose of the

thrust bearing is to regulate the relative positions of spindle and cylinder, it can, of course, take some load. The single-flow reaction turbine is designed to be balanced and free from end thrust, but the possibilities of an end thrust do exist. When starting up a new machine, the direction and amount of the thrust must be determined, and a balance obtained by adjusting the blading. Unless this end thrust is carefully balanced, the thrust bearing will wear, with consequent trouble at the dummies. The importance of correct balance and thrust adjustment is so great that some further provision than that commonly provided for the purpose would prove a great advantage, especially for repair and overhauling on site.

Oil Service.—The conditions to be met are continuity of supply and efficient filtering and cooling arrangements. Practically the universal system is to supply oil under pressure either direct from the pump or from an overhead tank. The advantage of the tank is that it can act as a reserve in case of pump failure, and also be used to flood the bearings before starting up. For moderate sized units the self-contained system, *i.e.*, turbine driving its own pump, is undoubtedly the best, but for extensive stations of large units the independent central system has many advantages. For self-contained sets a small hand pump for flooding the bearings before starting up is a cheap and desirable addition. A small horizontal steam pump is sometimes used for this purpose, in which case it also serves as a standby in case of need. The problem of bearing lubrication on the turbine differs in some important respects from that on a double-acting reciprocating engine. There is no reversal of pressure on the journal, and consequently no knock to be absorbed. In addition to lubricating the bearings the oil has to carry off a much greater quantity of heat than on an engine, for, besides the heat generated in the bearing, heat is conducted along the shaft from those parts in contact with the steam. The quantity of oil required to be passed through a similar bearing per unit of time is much greater than in reciprocating-engine

work, and provision must be made for a continuous flow through the bearing. Except to ensure the bearings being flooded with oil there is no need for pressure, as the oil is drawn between the journal and bearing in the same manner as with the oil bath in the experiments carried out by Mr. Beauchamp Tower for the Research Committee of the Institution of Mechanical Engineers.

Although the velocities and pressures used in those experiments are not such as are common in turbine work, still much can be learned by a study of the distribution of pressure in the bearing and the results of the various methods used for feeding in the oil. One highly-successful method for solid bearings is as follows: The top half of the bearing only touches the journal by a narrow strip along the vertical center line and around the ends of the bearing, leaving a pocket on each side. The strip along the top is to prevent the shaft from rising, and the strips at the ends form the pockets which are used to provide an oil bath. The lower half of the bearing is relieved at the horizontal center line for a distance corresponding to the pockets in the top half to prevent the journal being nipped. This also serves to feed in the oil. It extends for a small part of the circumference and is tapered off to the bore of the bearing. The oil inlet is in the top half of the bearing on the downward side considering the direction of rotation of the shaft. The oil is carried round by the shaft and discharged into the pocket on the other side. Grooves are cut through the strips at the ends of this pocket to allow a proportion of the oil to escape and insure a sufficient circulation. Of course, a quantity of oil escapes all round the bearing, but it is usually necessary to add some grooves in addition. No grooves whatever should be cut in the bottom half of the bearing, as they only allow the oil to escape and materially reduce the load which could otherwise be safely carried. A consideration of the distribution of oil pressures, as recorded in the tests previously mentioned, will make the reason obvious.

The oil leakage, where the shafts pass through the bearing

pedestals, has proved a source of complaint. The thin brass scraper rings, which have been largely used to prevent the oil creeping along the shaft, are inadequate. The positive oil thrower, universally used on enclosed splash and forced-lubrication engines, however, usually meets the case, although the fan action of the generator is much greater with turbine-driven sets. This produces a region of low pressure around the pedestal, where the shaft passes out, and induces a current of air to pass through the pedestal so as to suck out the oil. In cases where clearances have been cut fine this point has assumed great importance, owing to oil getting into the generator windings. It is especially difficult to prevent leakage when, in addition to the natural fan action of the generator, devices are included in the generator design to induce a current of air for ventilating purposes. In such cases the only absolute security is to isolate the end of the pedestal from the suction effect. Except for very small pipes, flanges should be used with metal-joint rings. Any other packing material is affected by the oil, with consequent leakage. Much of the oil piping is exposed to view, and any slight weeping which would not be of importance on an enclosed engine is highly objectionable for the sake of appearance. When the turbine drives the oil pump there is a large choice of the designs which can be employed. There is the ordinary plunger pump with valves, the valveless plunger pump universally used on forced-lubrication engines and several designs of rotary pumps.

Each type claims some advantages, but owing to the great success of the valveless pump and the confidence inspired by its wide and extended service, it will naturally take a large share of the turbine work. In view of the success which has attended the simple oil-straining system adopted on forced-lubrication engines, the methods used with many turbine installations are very surprising. In some cases a small box, containing several screens of wire gauze or calico, is connected with the delivery side of the pump, and about 10 per cent. of the discharge is by-passed through the strainer. It

is claimed that the filtration of this volume is sufficient to keep the whole body of oil in a satisfactory condition. In other designs the oil flows over perforated trays, from the under side of which hang bags made of calico or similar material. The oil, being hot and thin, percolates through and falls into a tank underneath. The upkeep and attention required to keep these bags in a satisfactory condition must be a considerable item. The objection raised to putting the strainer on the pump suction, which is commonly done with forced-lubrication engines, is that, should the strainer become clogged, the oil is cut off. One method of avoiding this is to arrange the strainers so that the oil gravitates through them, and in the event of them becoming clogged the oil overflows into the suction chamber. As, however, it is usually impossible to arrange much gravity head, the strainer surface required becomes much greater than where the head due to the suction pump is utilized. That some strainer is absolutely necessary in commercial service experience has amply proved, and if accessibility is provided there is no reason why the system, which has proved successful with the reciprocating engine, should not do equally well on the turbine.

The oil-cooling problem is a very important one, and is much more difficult than is commonly imagined. Temperatures of 120 degrees to 130 degrees F. for the oil leaving the bearing are not uncommon. Some engineers advocate 150 degrees to 160 degrees F. as being quite safe with suitable oil. The oil to the bearing is usually some 15 degrees to 20 degrees F. less than that at which it leaves the bearing. All pipe joints must be metal to metal and positively locked to prevent leakage, so that designs, on the ordinary condenser lines, with packed glands, are out of the question. Copper coils immersed in a tank of oil, with the cooling water passing through them, are notoriously inefficient, owing to the cooled oil adhering to the outside of the tubes and acting like a blanket. Pumping the oil through the coil with the water outside is a considerable improvement. To obtain the maximum cooling capacity per square foot of tube surface, the

counter-flow system should be embodied in the design, and the tank so arranged that the fluid outside the coils is obliged to flow along their whole length and be brought intimately into contact with them. Provision must be made for examination and cleaning, and the more readily this can be done the greater the likelihood of the cooler being kept in an efficient condition. The coils should be well clamped and supported to prevent vibration. Owing to the persistency with which oil permeates any porous metal, special attention must be given to all castings which will contain oil, whether under pressure or otherwise. They should be so designed that no chaplets need be used, and all liability to porous metal must be avoided. Testing under water pressure will locate any leaky spots and possibly save much trouble and expense later. In some cases oil indicators are fitted on each bearing. Except under special circumstances, this is quite unnecessary, and a pressure gauge connected to a suitable point in the system is all that is required. We consider that the multiplication of safety devices, unless absolutely necessary, does much harm, owing to the distrust they inspire by the suggestion of possible failure.

Governing.—The system of operating the governor valve by means of steam or other working fluid in a relay cylinder, or electrically, has been very popular in turbine work. In view of the great success attending the direct-operated governor valve used on high-speed engines, there can be no doubt that this method, which is much simpler, can be equally successful on turbines governed by throttling, and requiring up to 8-inch or 10-inch diameter valves.

The oscillating gear in conjunction with a steam relay cylinder, commonly used on one type of turbine, certainly overcomes the friction of rest; but, if this is of vital importance, why have not the engine builders been driven to the same solution of the difficulty?

There is no difference in steam consumption, for the results with the oscillating gear follow the straight-line law characteristic of throttle governing with a direct-connected

valve. Supporters of the oscillating gear contend that with a turbine the friction of rest has a greater effect in producing "stickiness," owing to the even turning moment of a turbine, whereas the comparatively uneven turning moment of a reciprocating engine tends to keep the governor and gear continually on the move, although so slightly as to be practically not apparent. However, in order to obtain satisfactory operation when running in parallel, some turbine makers have found it necessary to reduce the travel to the least possible amount and to increase the periodicity of the oscillations to about 250 per minute, thus reducing the valve beat to a small vibration, so as to tone out the impulses given to the rotating part by the gusts of steam. The trouble probably arose with sets where the rotating parts were unusually light. In view of these facts, failure from this point need not be anticipated. That indifferent governing has been experienced with direct-operated valves may probably be accounted for by other reasons. With the oscillating gear the valve seats itself at each beat, when on light loads, so that both seats must be the same diameter, involving a loose seat ring. If uneven diameters are used "hunting" will result at light loads. An air dashpot is commonly arranged on the valve spindle; but, as the travel is small when the valve is seating, the dashpot is of little service when most needed.

To overcome this difficulty an arrangement of joggle links is used by some builders to vary the lift of the valve with the load so that the lift is increased as the load decreases. In any case, however, the loose seat ring is a weak point. Also the beating soon wears a facing of considerable width on the seats and causes leakage should the valve be required to shut the steam right off. This reason has contributed to the undue importance given to the safety governor valve. Engine builders long since found out the impossibility of making and keeping a double-seated valve tight with anything wider than a knife-edge contact. With a direct-connected valve of the design commonly known as the Belliss type the seats never come into contact except when the governor flies to the

extreme outer position, so that the seats keep in good condition. In that design the seats can be made of slightly different diameters, so that a loose seat ring is not required. The shape of the valve and seating also lends itself to a successful design for expansion, especially under superheated-steam conditions. The valve should be carried on a small-diameter spindle passing through a long bush to prevent it being much out of balance and to obtain steam tightness with a minimum of friction. No adjustable stuffing box should be used, as it may be screwed up sufficiently to nip the spindle. In designing the connections care should be taken that no bending moment is put on the valve spindle, as, owing to its small diameter, it is easily distorted slightly and then stickiness results. The valve spindle is the only delicate point with the direct-connected governor, but that it can be made absolutely reliable is amply demonstrated by the thousands of sets in successful operation. The connection between valve and governor should be direct, rigid, contain few joints, and be as light as possible to reduce inertia. For this reason rods and rocking shafts of large-diameter tubing should be used to obtain rigidity with the miuimum of weight. The governor is a detail showing great divergence in design. The elaborate designs, built up of many parts, often defeat the very objects for which they are produced. Here, again, engine builders have evolved by experience simple designs, which are not only much cheaper to make, but wear far longer and give better results under service conditions than more elaborate kinds. Summed up, the engine builders' experience amounts to:—(*a*) Few parts, designed to facilitate accurate workmanship; (*b*) few joints, with ample bearing surfaces; (*c*) plain pins, instead of knife edges; and (*d*) forced lubrication throughout.

It has been found advantageous, with a direct-connected valve, to provide a more powerful governor than at first consideration would seem necessary. The cost is very small, as the speed can be kept high. Although the power may never be required, it places all fear of possible trouble from friction

out of the question. Compared with a steam relay cylinder and oscillating gear, the direct-connected valve possesses far less possibilities of failure, is adjusted much more easily and requires less attention in operation. The bearings requiring hand lubrication are very few, while their movement is extremely small.

With a relay cylinder actuated by a fluid, operation depends on the pump. The objection to all relay systems is their tendency to lag or overrun, and also to stick unless kept continually reciprocating. The governor is usually fixed on a reduced speed shaft driven by the main shaft through a worm and wheel. The main shaft has adjustable bearings, but the second shaft is often not made adjustable. Consequently the worm and wheel are not correctly lined up at the pitch lines, with resultant excessive wear and tear. With oscillating governor gear the worm-wheel shaft is horizontal, and drives the gear by an eccentric or cam on this shaft. The governor is fixed on another vertical shaft driven by bevel wheels or skew gearing from the horizontal shaft. With a direct-operating governor gear this second shaft and gear wheels can be dispensed with, and the possibility of trouble with this set of gear wheels will be avoided. When a reduced speed shaft is required to drive a plunger or rotary oil pump there may be some advantages by fixing the governor on this shaft, whether it be horizontal or vertical; but probably with a direct-operating gear it will ultimately be fixed on the main shaft. Naturally the desire arises to develop some form of rotary pump suitable for fixing on the main shaft, and so avoid all gearing. This would slightly increase the overall length, but the positive drive and elimination of all gearing would more than compensate for a slight increase in length. The safety governor is mainly a concession to the fear of a possibility which should be practically unknown under service conditions. The consequences of a turbine running away would, of course, be very serious, but there should be no reason to anticipate the failure of the main governor more often than on reciprocating engine sets, and far too much emphasis has

been given to this point. Its services are required only as a last means to prevent disaster, and every care should be taken to insure successful operation under all possible conditions which may arise. For this reason both governor and valve should be entirely independent of any other details, and the governor should be placed on the main shaft, so that no failure of gearing can affect it.

It should be designed so that when it commences to move it will fly to its extreme position on a slight increase of speed and generate ample power to move the gear. Some designs of safety governor valves are operated by a differential steam piston in a vertical cylinder, so proportioned that the valve is supported and held open by steam pressure. The safety governor opens a small valve exhausting the steam from the underside of the piston, so that the valve falls by reason of its weight and the steam pressure which is admitted on the top of the piston. Other designs utilize the main stop valve for the purpose, and they combine the usual hand wheel and spindle for opening the valve, with a steam piston or spring-loaded devices for closing the valve automatically when operated by the safety governor. For reasons already stated this appears to be undesirable. In case of failure both hand and automatic control is lost. The liability of steam relay systems to stick when not kept continually in motion neutralizes any advantages of these designs. A valve of the same design as the direct-connected main governor valve previously considered, and loaded with a spring or dead weight, and operated with a trip gear from the safety governor, offers less possibilities of failure, and is positive in its action. It can be so designed that before putting the machine on load the valve and gear can be tested by hand in a few seconds, thus insuring it being in working order. Butterfly safety valves have done good service on engines, but the rapidity with which a turbine gets away makes it desirable absolutely to cut off all steam, and this cannot be done with a valve of the kind.

Exhaust Connection.—The conditions are similar to those at

the steam inlet. If there is more than a very short length of horizontal piping it is desirable to anchor the bend below the turbine to the foundations. This prevents the expansion in the horizontal piping from exerting a twisting effort on the turbine cylinder. A corrugated-copper expansion pipe or wrought-iron bellows pipe must be provided between the bend and turbine cylinder to take up the vertical expansion.

Concluding Remarks.—It seems almost superfluous to insist on the necessity of positively locking all pins on governor gear, and especially all bolts, nuts and studs in steam spaces, on valve seats, spindles, &c., yet many shut-downs have occurred through neglect of this point. All castings subjected to superheated steam should be annealed after rough machining and before finishing, otherwise permanent distortion will often occur when put in service. Special attention must be given in designing steam chests, valves, &c., to obtain forms which will expand evenly and retain their shape. It may be argued that many troubles have been experienced which are confined entirely to the turbine, but, considering the vast amount of pioneer work which has been successfully accomplished, and the world-wide development which is going forward, it is certain that the difficulties will be surmounted. —"The Engineer."

THORNYCROFT PARAFFIN MOTOR FOR THE ROYAL ITALIAN NAVY.

The engines illustrated are designed to be installed in two twin-screw submarine boats and are constructed in four-cylinder units, bolted together, making eight cylinders on each shaft. The dimensions of the cylinders are 12-inch diameter by 8-inch stroke. They are totally enclosed, and lubrication is forced to all bearings, those on the crank shaft and also the bottom of the crank case, being water cooled. In addition to this, the pistons and crank case generally are continuously cooled by sucking cold air, which is drawn through by an exhausting fan.

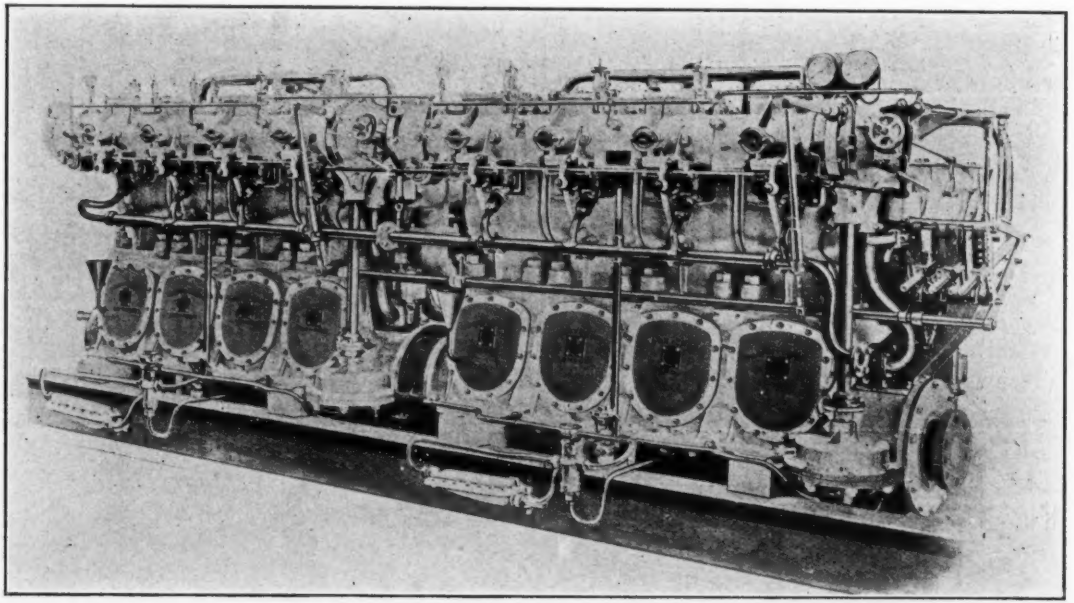
Facilities are provided for the removal and replacement of the pistons and connecting rods through the doors in front of the engine, thus rendering removal of the cylinders and access from the back of the motor unnecessary, an advantageous feature for submarine boats.

Cooling water is circulated by a separately-driven centrifugal pump, driven by either an electric motor or a small oil motor using the same fuel as the main engine. A great advantage of this method is that the motor may be cooled more rapidly after running, in case examination or adjustment becomes necessary. The separate drive also allows of a close regulation of the quantity of water to suit the needs of the engine, according to the nature of fuel used.

The special paraffin vaporizer is fitted with a variable exhaust bypass so that the temperature may be exactly graduated to the needs of the particular fuel used. This is very essential, as the oils used for fuel vary so greatly in the amount of heat required to vaporize them, and excess of heat is as harmful as too little. With a proper regulation of heat the engine or vaporizer never requires to be cleaned as there is no tar deposit. Trouble on this score is absolutely nonexistent with these engines.

An entirely novel feature is the reversing mechanism, replacing the usual method of using a double set of cams for running in either direction. The camshaft is so arranged that whichever direction the engine itself runs, the camshaft turns in one direction only, and to provide for this a reversible bevel drive, with positive clutches, is fitted. Starting in either direction is effected by means of compressed air, the valves controling which are cut off immediately the engine is firing. Low-tension magneto ignition and distributor are fitted in conjunction with a special form of make-and-break gear in the cylinders.

The consumption of fuel is very low, being about .7 pint of paraffin or petrol per brake horsepower per hour. The engines are designed with ample bearing surfaces and are in



ENGINES TO BE INSTALLED IN SUBMARINE BOATS OF ITALIAN NAVY.

every way suitable for heavy, continuous service. The total weight per four-cylinder set is 70 cwt.

The following table of results of a three-hours' trial is of interest:

Trial of 1 and 2, 8-cylinder 12 inches diameter × 8 inches stroke. Reversing.

Fuel used, Phœbus Paraffin; S. G., 0.820.

Consumption, 0.66 pint per B.H.P. per hour.

Time from start. *Hours.*	B.H.P.	Revolutions.
0	324	550
½	328	555
1	340	590
1½	327	595
2	318	595
2½	318	600
3	324	600

The average revolutions per minute were 582.5, and the average power 325.5 B.H.P. The equipment for each boat will consist of two eight-cylinder sets, driving twin screws, and together developing 650 B.H.P. The boats in which they will be installed are of 150 tons displacement, and have a radius of action of 500 miles at 10 knots speed. Their dimensions are 98½ feet by 14½ feet. The table of trial results is that taken during an official trial in the presence of a commission of inspection from the Ministry of Marine, Italy. The consumption of fuel, which is ordinary paraffin or lamp oil, amounting to 0.66 pint per B.H.P. per hour, is claimed as extremely low for engines of this type.—"Page's Weekly."

ASSOCIATION NOTES.

The regular annual meeting of the Society was held in the Navy Department, Washington, D. C., December 26, 1907, for the purpose of electing officers for the year 1908.

A count of the votes received resulted in the election of the following officers:

President, Commander R. S. Griffin, U. S. Navy.

Secretary-Treasurer, Commander Theo. C. Fenton, U. S. Navy, Retired.

Members of the Council, Commander F. C. Bieg, U. S. Navy; Commander B. C. Bryan, U. S. Navy; Commander H. P. Norton, U. S. Navy.

The following is the statement of the Secretary-Treasurer for the year ending December 31, 1907:

Received 1907:		
Dues and subscriptions	$4,031.82	
Advertisements	1,755.54	
Sales	740.85	
Interest	268.17	
Total receipts		$6,796.38
Balance (Cash) January 1, 1907		1,733.47
		$8,529.85
Expended:		
Printing and stationery	$3,872.89	
Engraving	417.52	
Salary, Secretary-Treasurer	900.00	
Purchase of Journals	115.00	
Articles paid for	80.00	
General expenses, including employment of clerk, postage, expressage and incidentals	146.25	
Purchase of one (1) $1,000 bond, Washington Railway and Electric Co.	815.50	
Total expended		$6,347.16
Cash balance		2,182.69

Available assets of the Society, January 1, 1908:

Cash balance	$2,182.69
Six (6) $1,000 bonds (cost)	5,215.50
Total	$7,398.19
Total value, January 1, 1907, cash and bonds	6,133.47
Net gain for year 1907	$1,264.72

This statement was audited by a committee of the Council and found to be correct.

THEODORE C. FENTON,
Commander, U. S. N., Retired,
Secretary-Treasurer.

R. S. GRIFFIN, Commander, U. S. N.,
President.